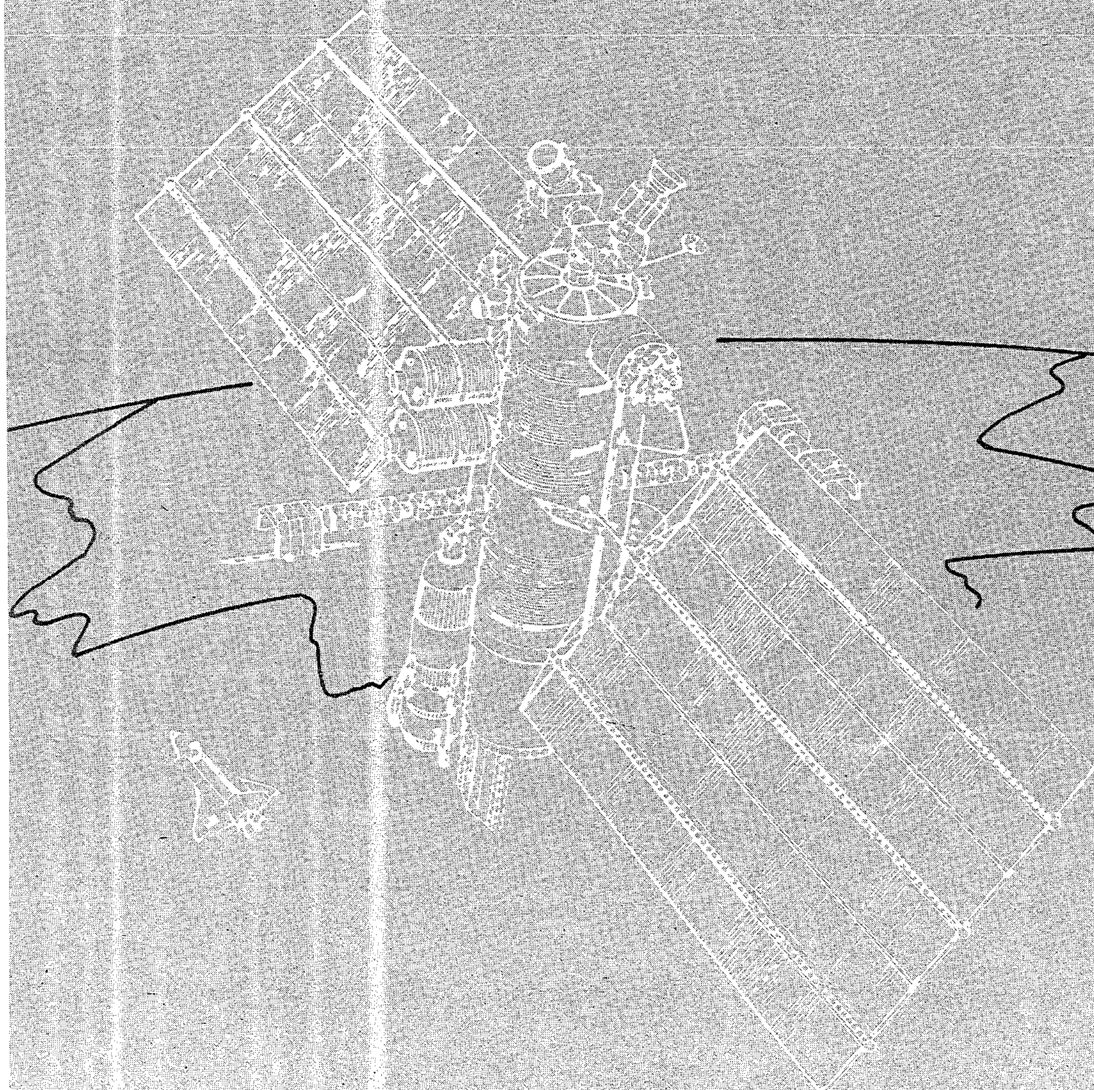
SOC-SE-02-02
Contract NASW-3686

NASA CR-173,321

Final Review/Executive Summary

April 1983



Space Station Needs, Attributes, and Architectural Options Study

MARTIN MARIETTA

NASA
National Aeronautics and
Space Administration

FOREWORD

This document is submitted in accordance with the requirements of Contract NASW-3686, Schedule Article II, and Contractor Task 5.3 of Attachment A Statement of Work. This document is the briefing material for the final review.

N84-18273#

SOC-SE-02-02
April 1983

Contract NASW-3686

April 1983

SPACE STATION NEEDS ATTRIBUTES AND ARCHITECTURAL OPTIONS

BRIEFING MATERIAL FINAL REVIEW

Prepared For:

The National Aeronautics
and Space Administration (NASA)
and The Department of Defense (DOD)

Prepared By:

Martin Marietta Aerospace
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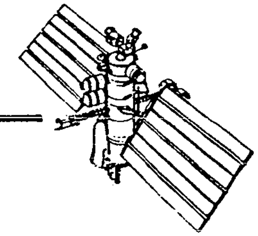
Program Manager: Sherman R. Schrock



Summary Results

Space Station Needs, Attributes

And

Architectural Options

Study

APRIL 5,1983

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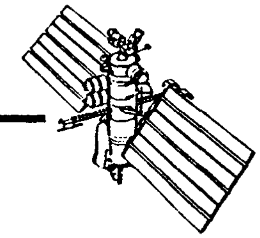
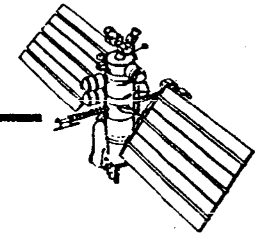
Summary Results



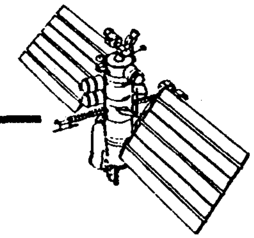
Agenda

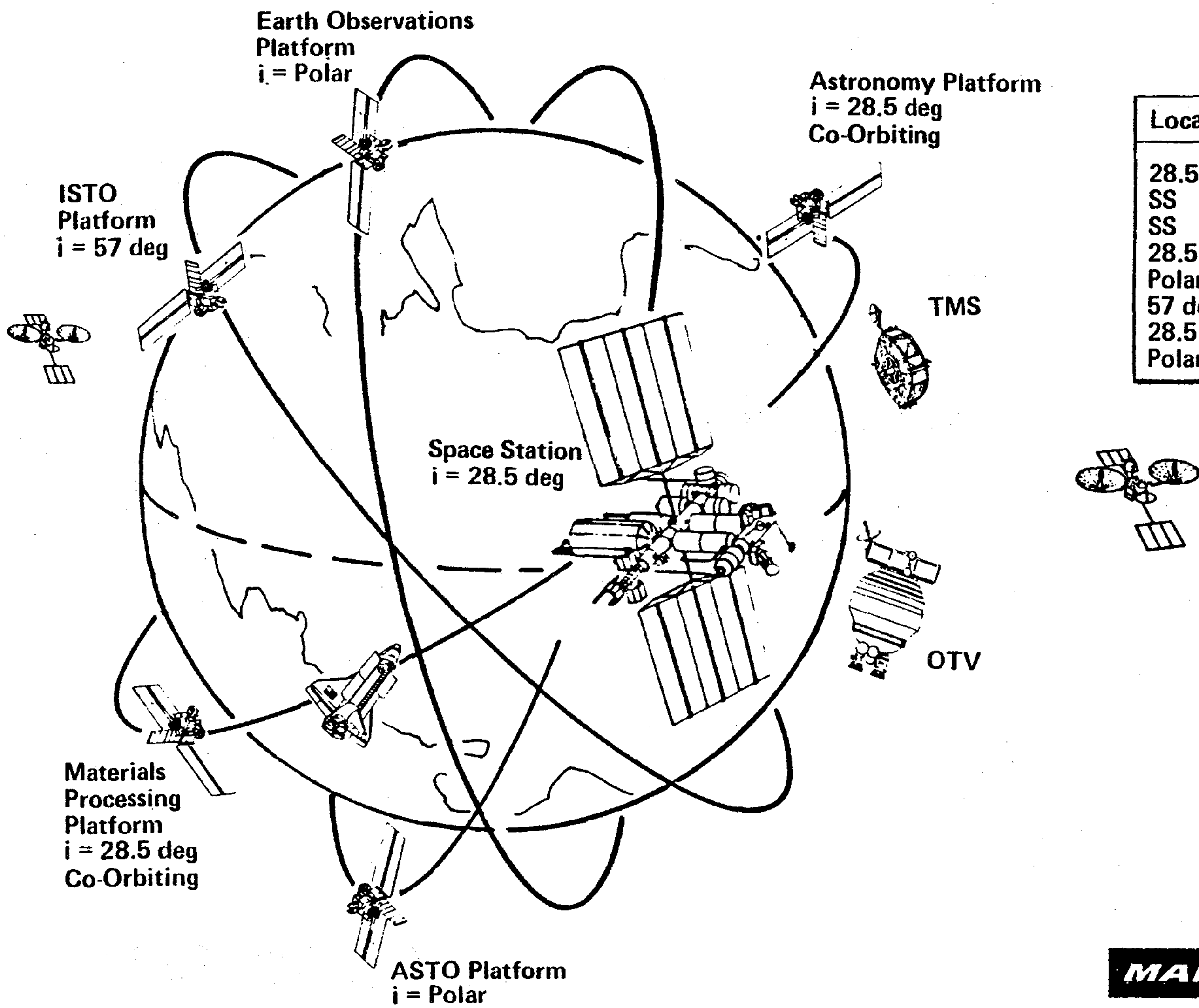
- Introduction
- Time Phased Mission Requirements & Attributes
- Program Evolution
- Space Station Architecture
- Key Technologies
- Associated Cost and Benefits
- Conclusions



Introduction

Space Station System Architecture



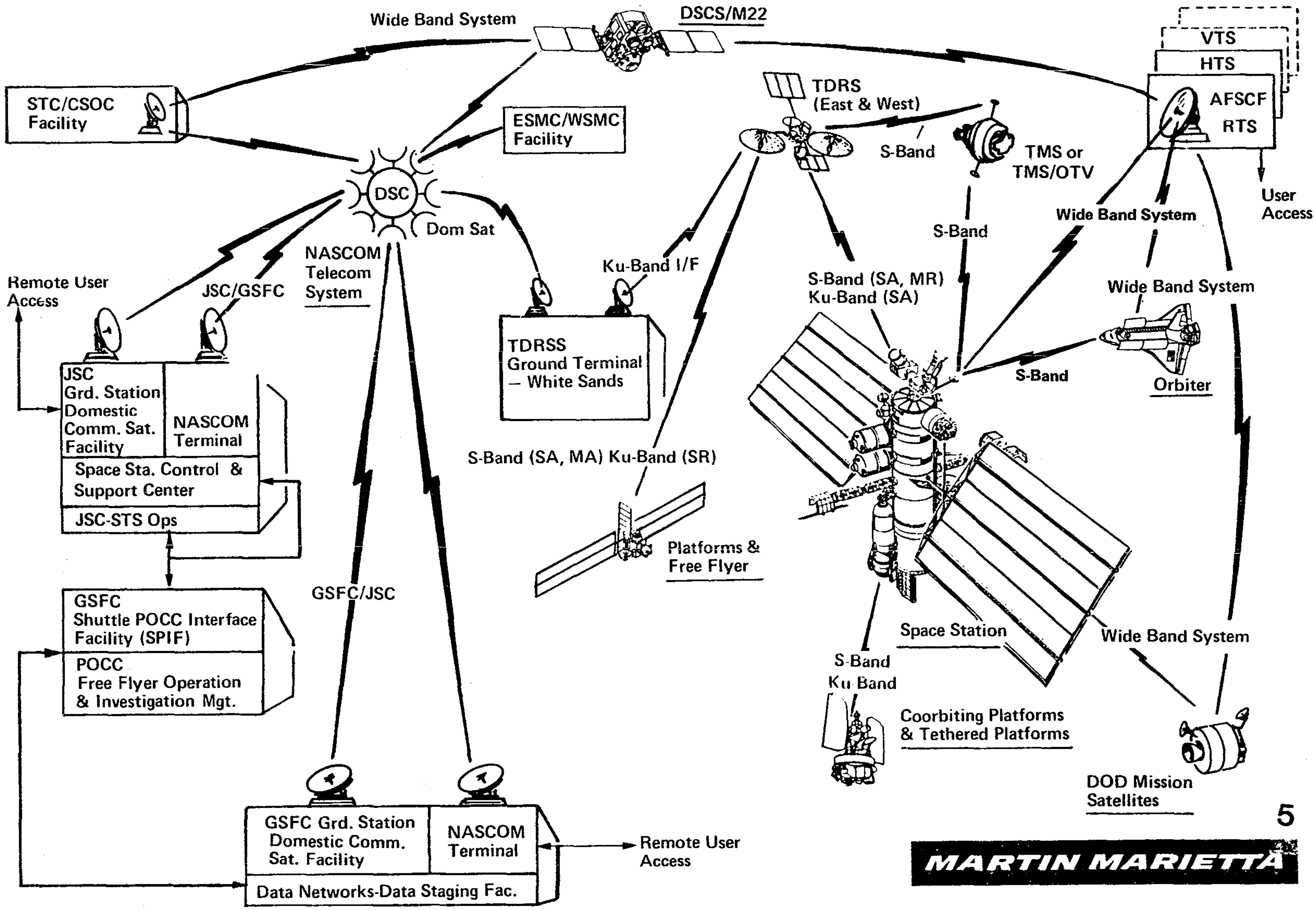


Location	Qty	Element
28.5 deg	1	Station
SS	2	OTV
SS	2	TMS/Servicers
28.5 deg	1	ASTR Platform
Polar	1	EO Platform
57 deg	1	ISTO Platform
28.5 deg	1-2	MP Platform
Polar	1	ASTO Platform

Functional Capabilities:

– Orbital Transfer/Retrieval
– Satellite Servicing
– Assembly
– Operational Services

Space Station Operations Architecture / Infrastructure



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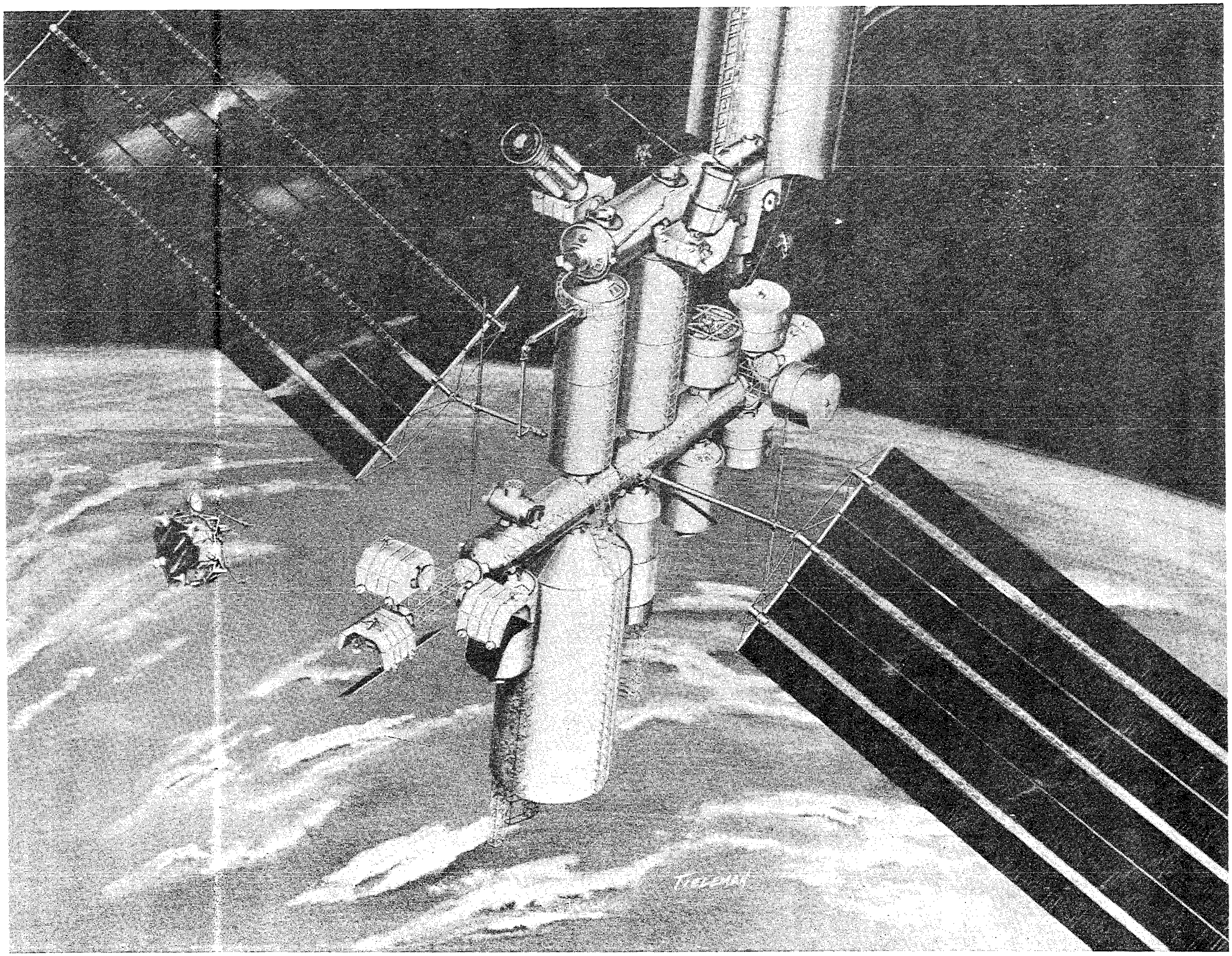
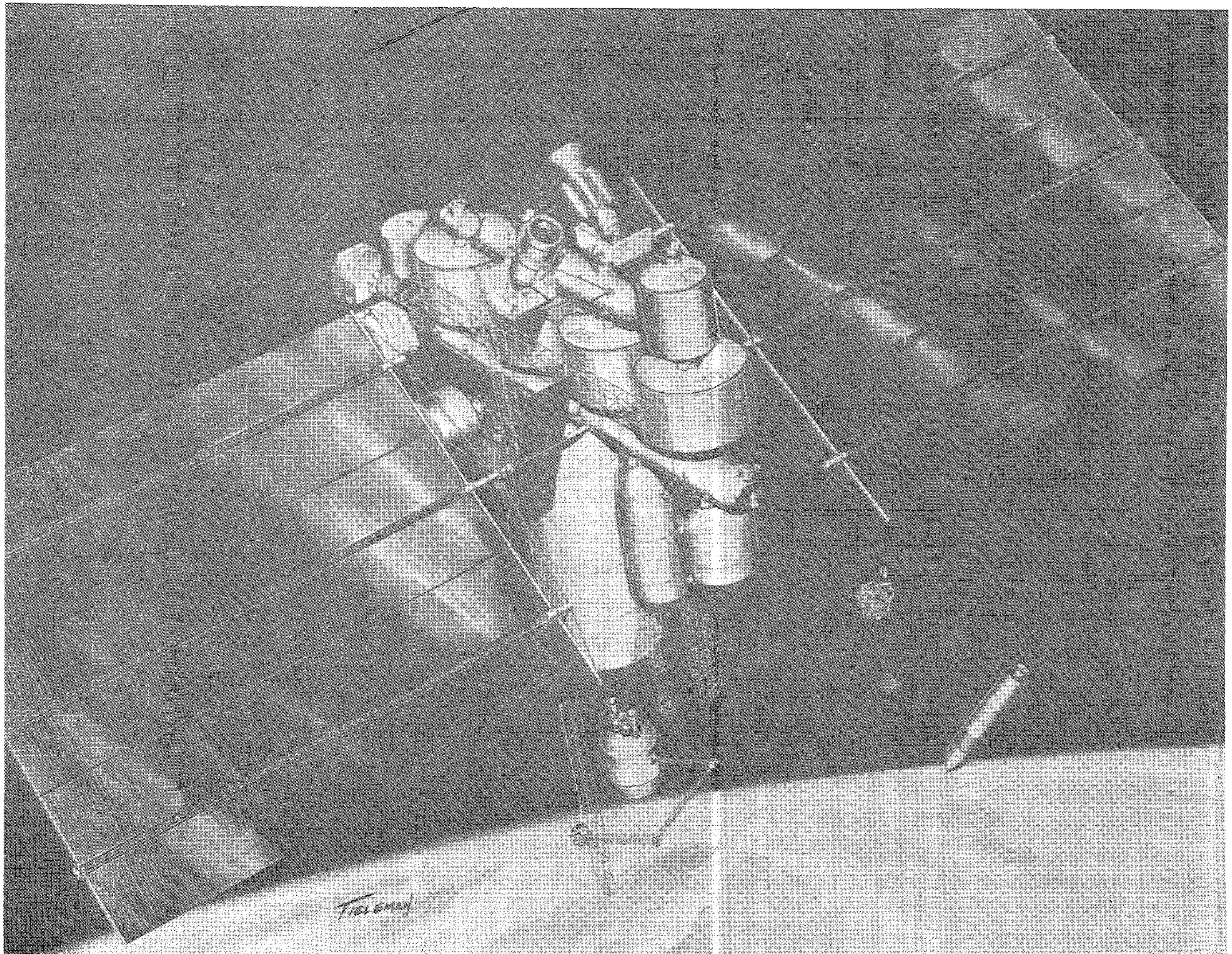
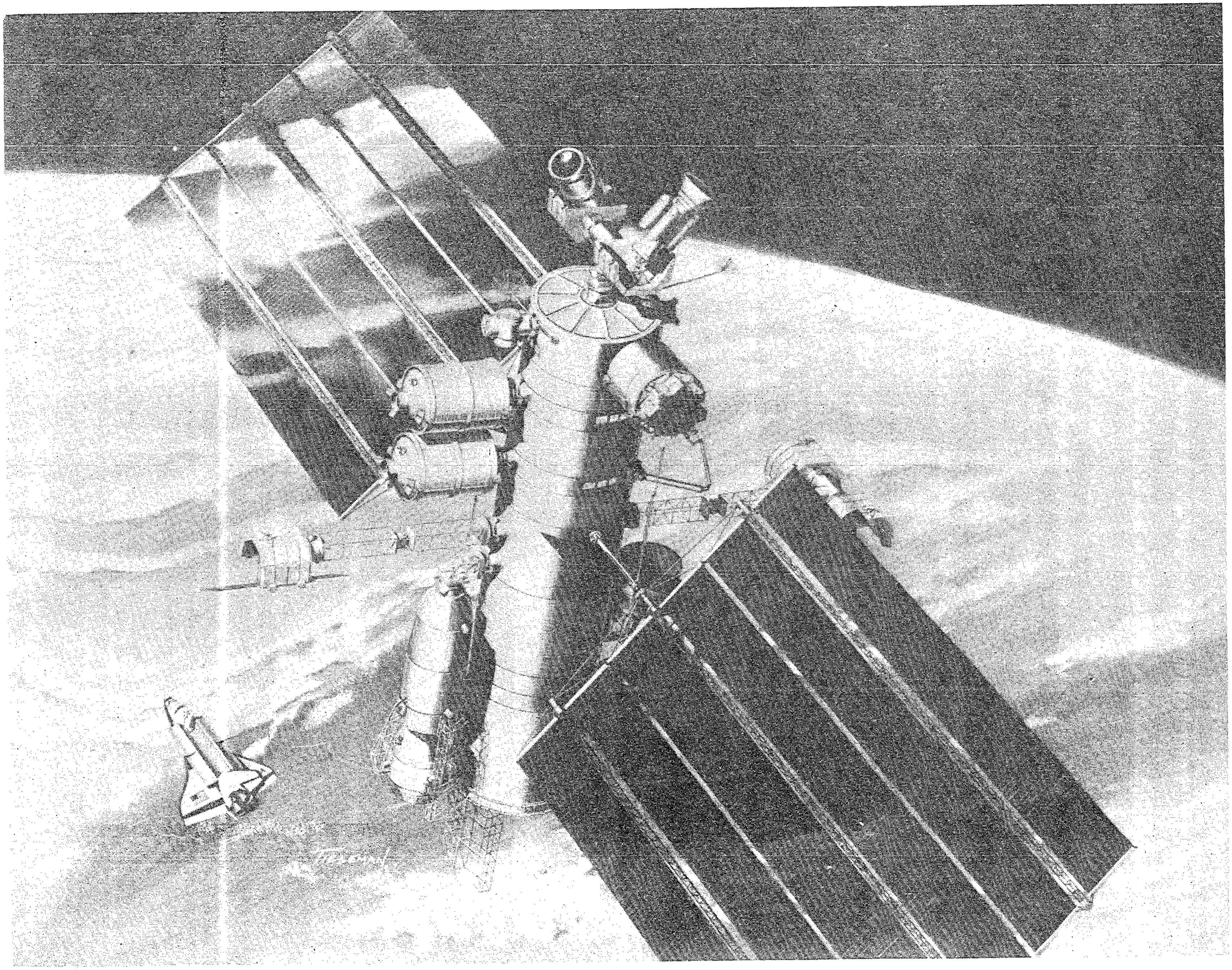


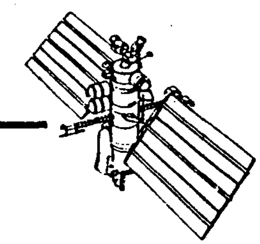
MODULAR CARGO BAY CONCEPT SPACE STATION



AFT CARGO CARRIER CONCEPT SPACE STATION

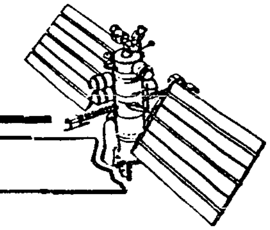


SHUTTLE DERIVED VEHICLE SPACE STATION



Time Phased Mission Requirements & Attributes

Affordable Mission Model Development



Consultation with and Validation by Recognized Authorities

Composite Mission Model

Catagories	Number of Missions 11/82	3/83
Science	138	191
Applications	19	28
Commercial	63	114
Operations	53	56
Total	273	389

Analyses & Trade Studies

Mission Optimization
- User Objectives Coordination
- Sensor Set Optimization
- Multisensor Data Processing
- Sensor Combination/Colocation
- Eliminate Duplication

Cost Validation
- Budget Projections
- Discipline Cost Constraints
- Affordability Evaluation

Time Phasing
- Mission Objectives
- SS Evolution
- Cost Constraints

System Utilization
- STS
- Space Station
- Platforms
- Independent Free Flyers

Affordable Mission Model

SS | Platforms | IFF

Catagories	Number of Missions
Planetary Science	11
Earth Observation	14
Space Physics	11
Astronomy/Astrophysics	20
Solar Physics	8
Life/Biological/Medical Sciences	14
Materials/Space Processing	20
Communications	64
Technology Development	23
Total	185

Trade Study Results

- Realistic/Affordable Mission Model
- Meets Users Needs
- Realize Cost Savings
- Decreased Required STS Flights

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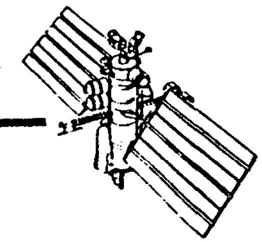
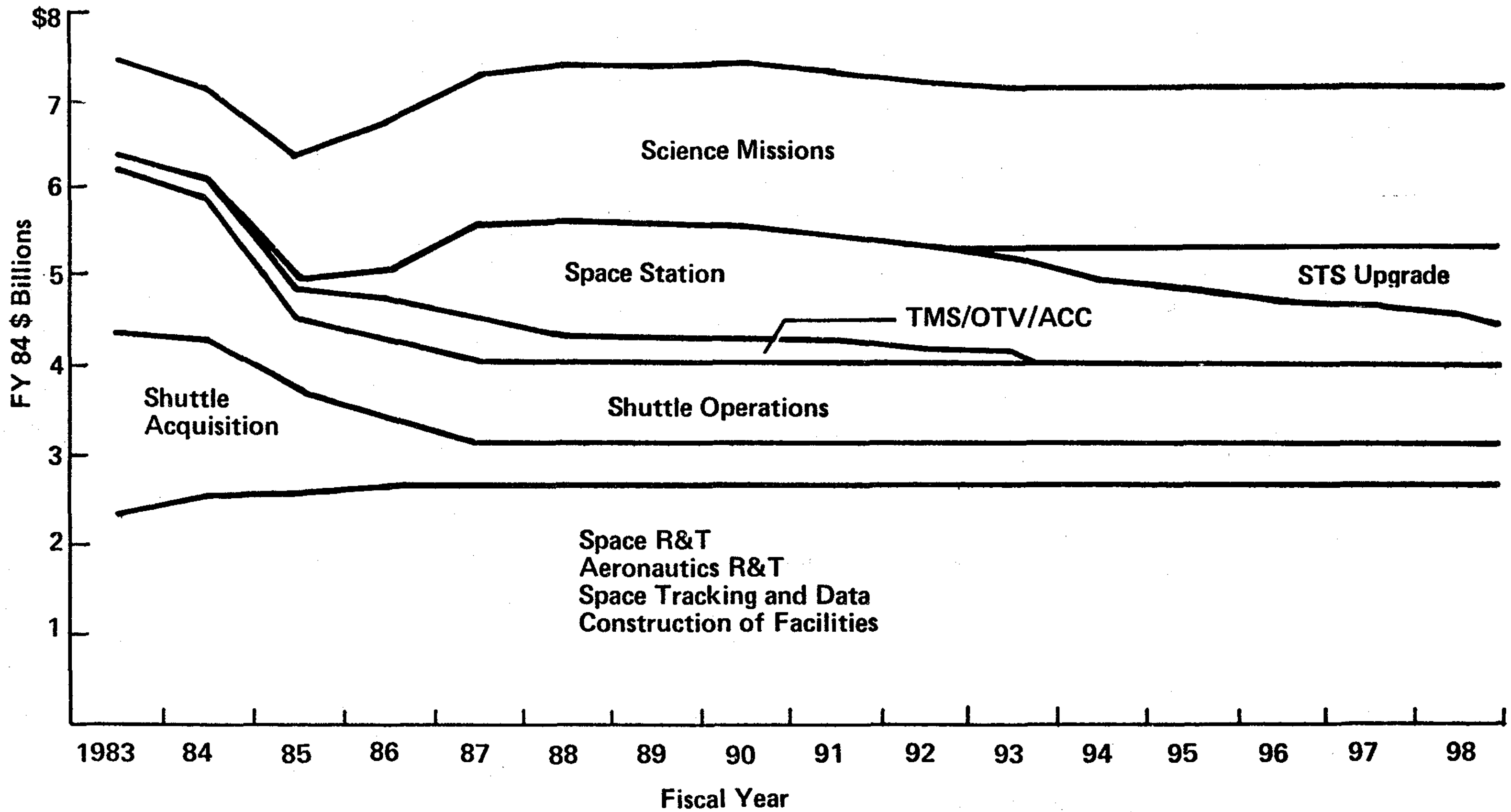
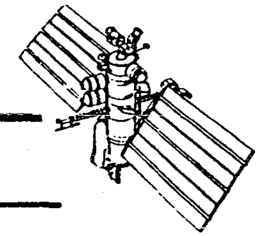
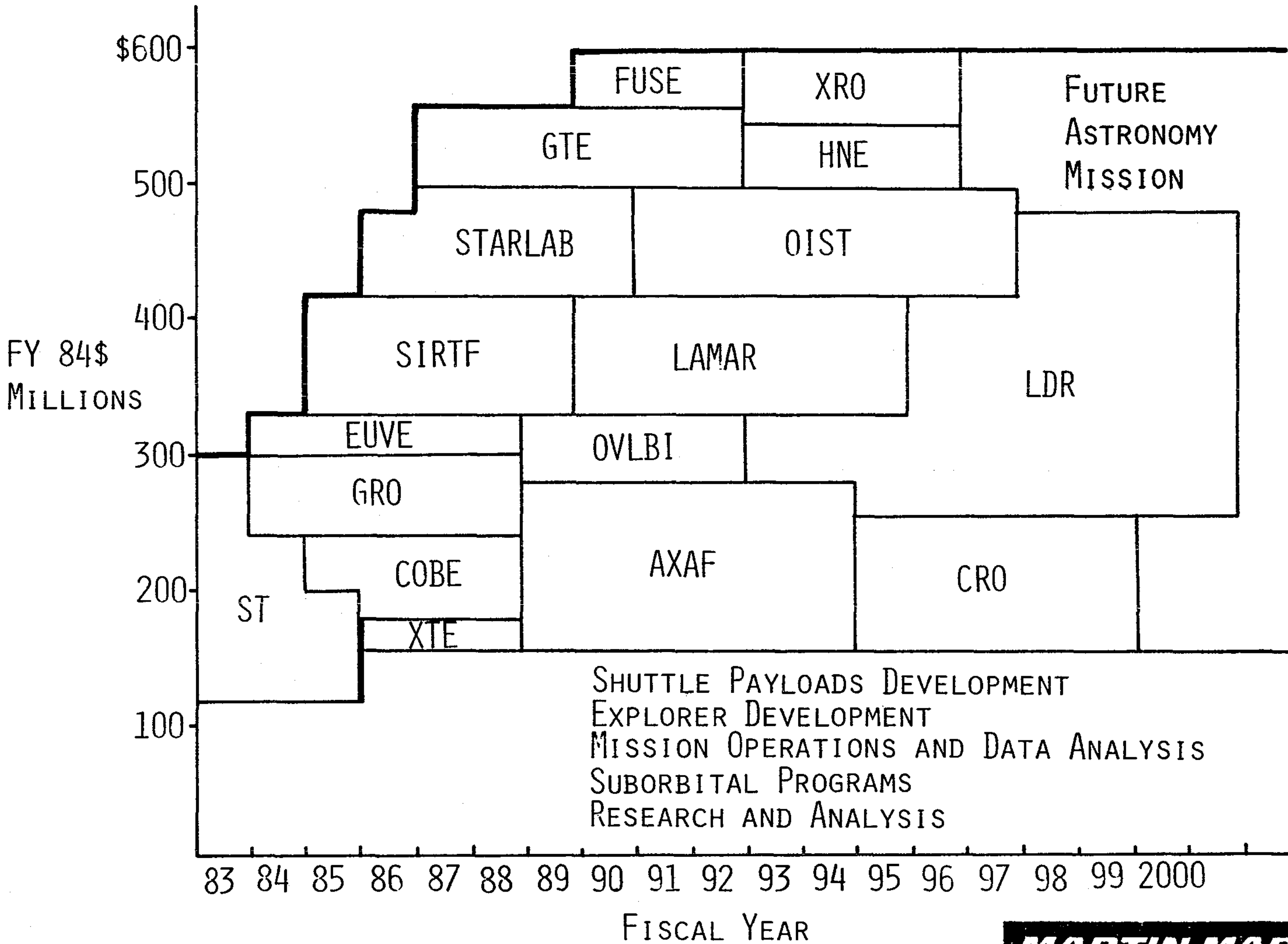
NASA Budget Projection – Affordability Analysis





Astronomy Affordability Analysis





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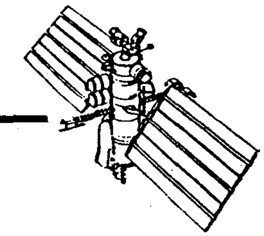
User Functional Support Requirements



TOTAL SPACE STATION SUPPORT REQUIREMENTS

Orbit Transfer (O/T)	- 83
Repair/Resupply (R/R)	- 95
Operations Control (OPS)	- 86
Basing/Subsystem Support (S/SYS)	- 85
Checkout & Verification (C/O)	- 86
Assembly & Large Space Structures (ASSY)	- 15

Technology Development
OPS - 23 C/O - 22
S/SYS - 23 ASSY - 5

Materials Processing
R/R - 20 S/SYS - 19
OPS - 20 C/O - 20

Communications
O/T - 62 S/SYS - 2
R/R - 13 C/O - 4
OPS - 1 ASSY - 1

Life Sciences
R/R - 14 S/SYS - 14
OPS - 14 C/O - 14

Earth Observations
O/T - 1 S/SYS - 13
R/R - 14 C/O - 14
OPS - 13 ASSY - 1

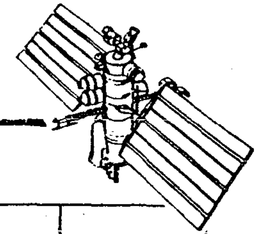
Space Physics
O/T - 6 S/SYS - 3
R/R - 7 C/O - 6
OPS - 4 ASSY - 1

Solar Astronomy
O/T - 2 S/SYS - 4
R/R - 20 C/O - 6
OPS - 4 ASSY - 7

Astronomy
O/T - 2 S/SYS - 4
R/R - 20 C/O - 6
OPS - 4 ASSY - 7

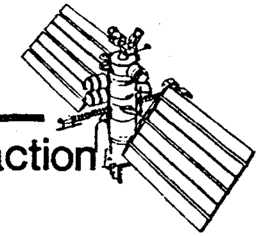
Planetary
O/T - 11

Mission Accommodation Allocation–28.5° Option

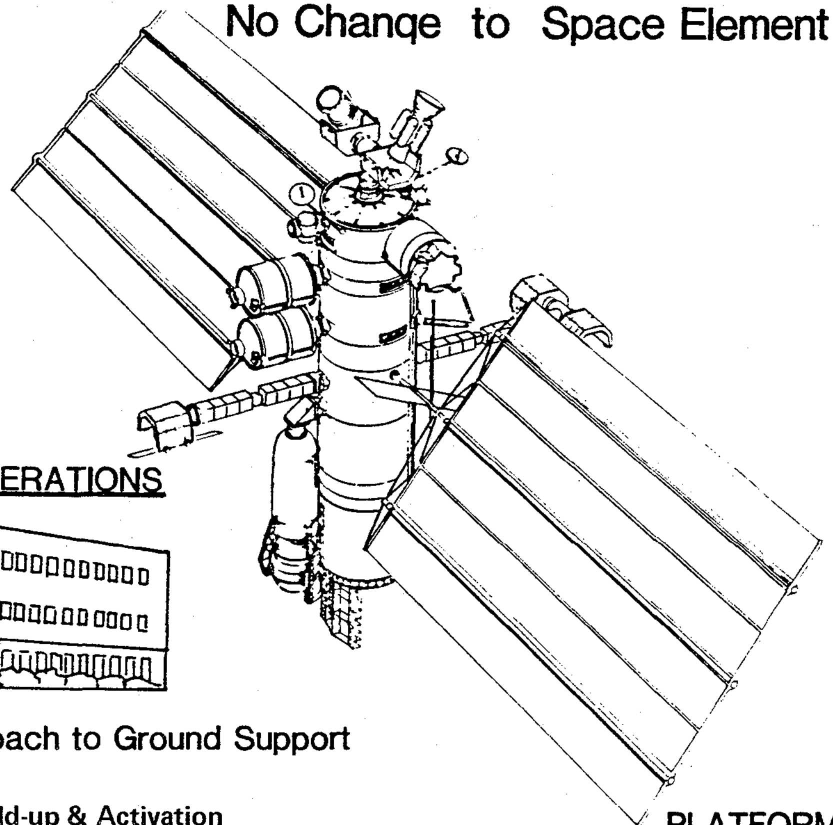


Category	Orbit Transfer/ Support	Space Station	Platforms					Total
			Earth Obs	ISTO	ASTO	Mat Proc	Astronomy	
Planetary	11	-	-	-	-	-	-	11
Earth Obs	4	4(T→P)	6	-	-	-	-	14
Space Physics	6	1	-	2	2	-	-	11
Astronomy	15	2(T→P)	-	-	-	-	3	20
Solar Astronomy	2	-	-	-	-	-	6	8
Life Sciences	-	14	-	-	-	-	-	14
Material Proc.	6	4	-	-	-	10	-	20
Communications	63	1	-	-	-	-	-	64
Technology Develop.	-	23	-	-	-	-	-	23
	107	49	6	2	2	10	9	185

Operations Concept



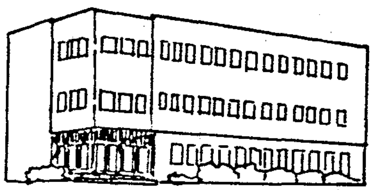
No Change to Space Element Infrastructure Interaction



SPACE STATION

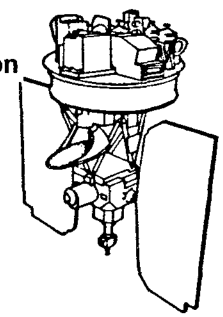
- Operations Control
  - Onboard Crew Takes More Responsibility
- Telepresence Control
- Operations Centers (Master & Backups)
  - Plan Onboard Activities and Manning Requirements.

GROUND OPERATIONS



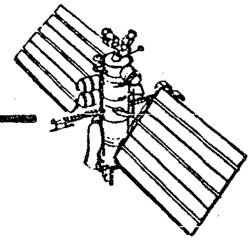
New Approach to Ground Support

- Initial Build-up & Activation
  - Business As Usual
- Decreasing Levels of Manning during Evolution
  - Rely More on Flight Crew
- Final Station Configuration & Operations
  - Relay Heavily on Flight Crew
  - Critical Parameter Monitoring
  - On Call Technical Support



PLATFORMS & SATELLITES

- Coorbiting Platforms (Space Station Control)
- Free Flying Platforms & Satellites (Ground Control)

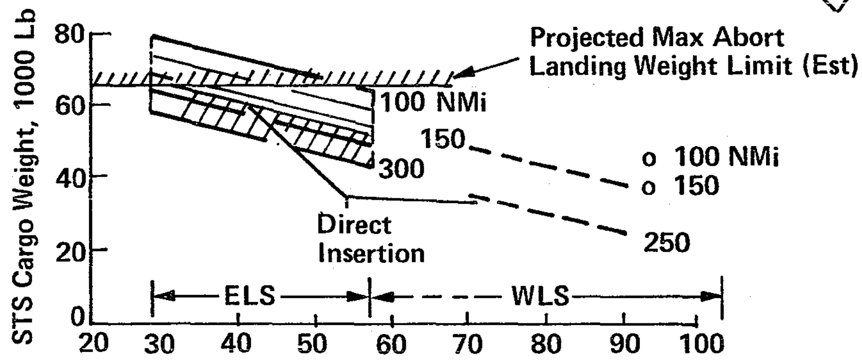


Mission Analysis Trades Summary

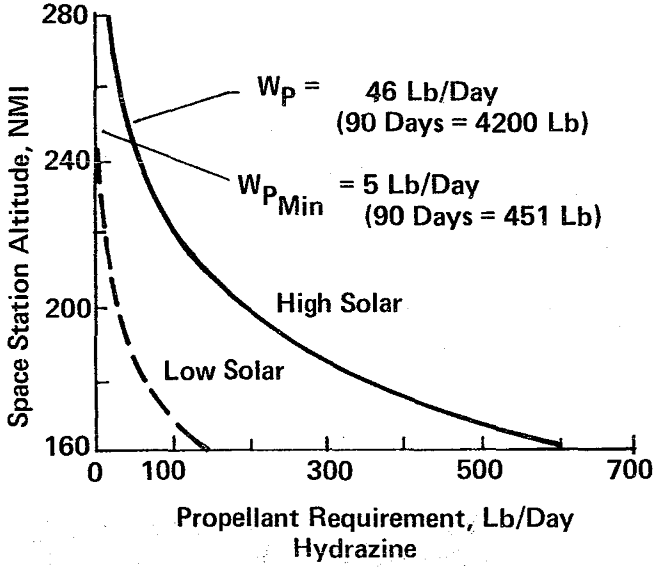
Summary

- o Launch Site - ELS
- o STS Selected Orbit Altitude - 250 NMi
- o Recommended SS Orbit Incl. - 28.5 deg

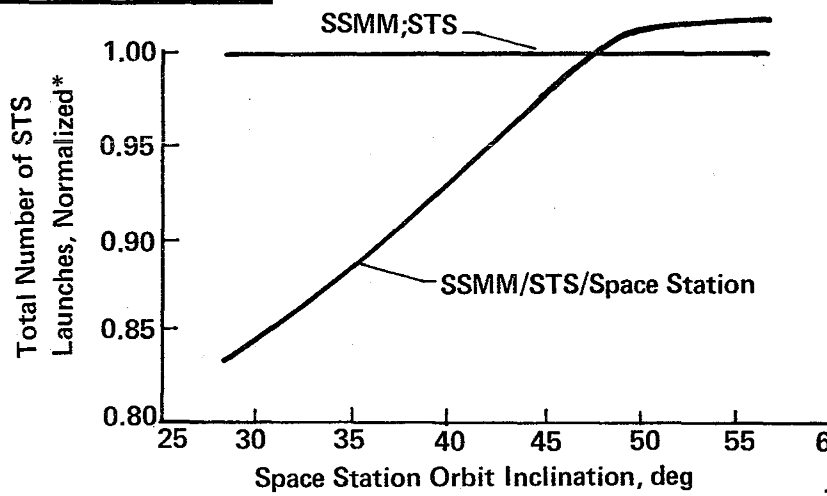
Location = ELS



Altitude = 250 NMi



Inclination = 28.5 deg



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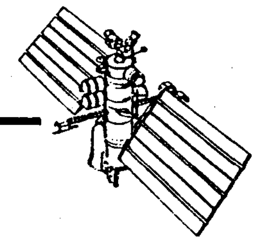
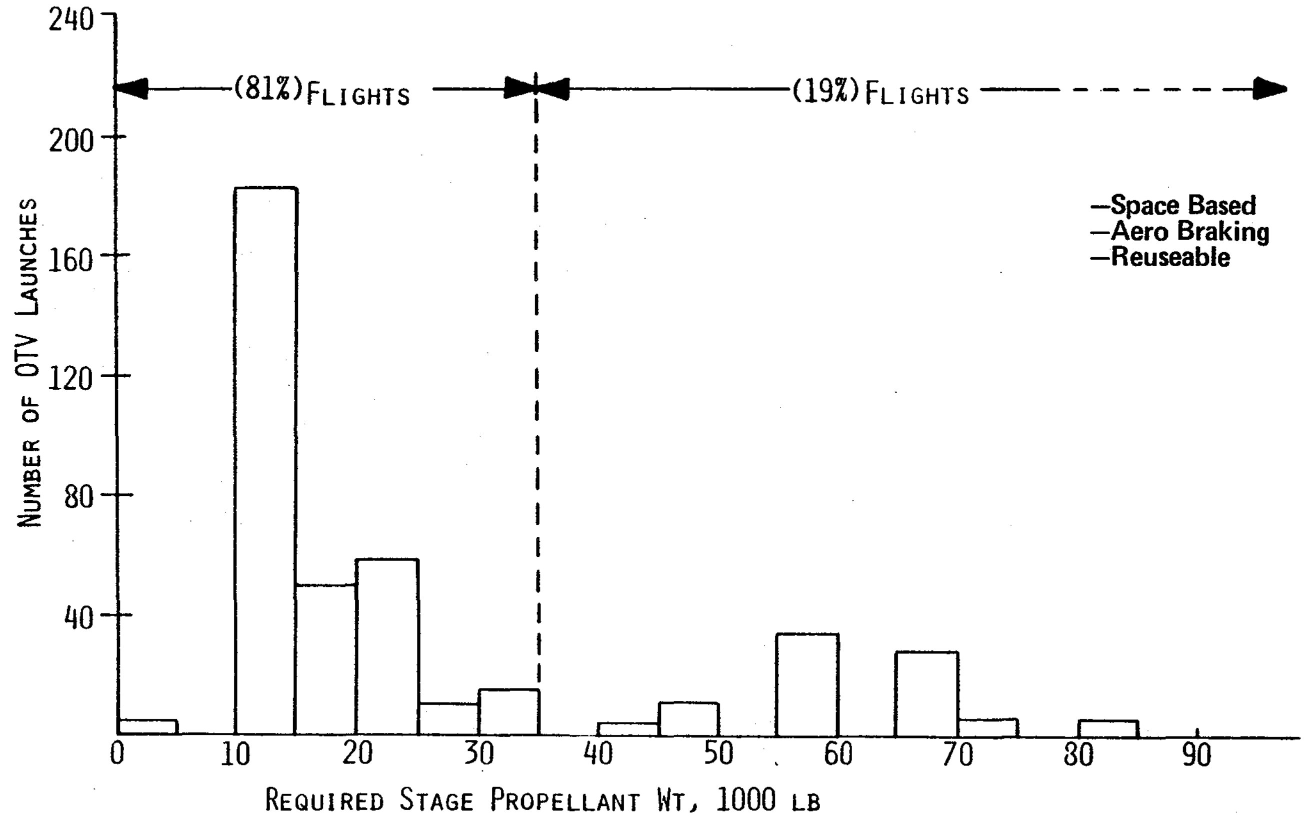
OTV Characterization Study





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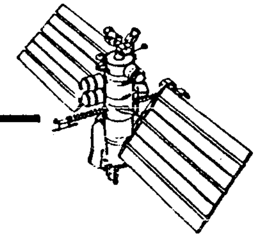

Program Evolution

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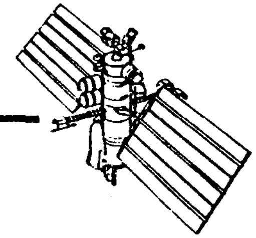
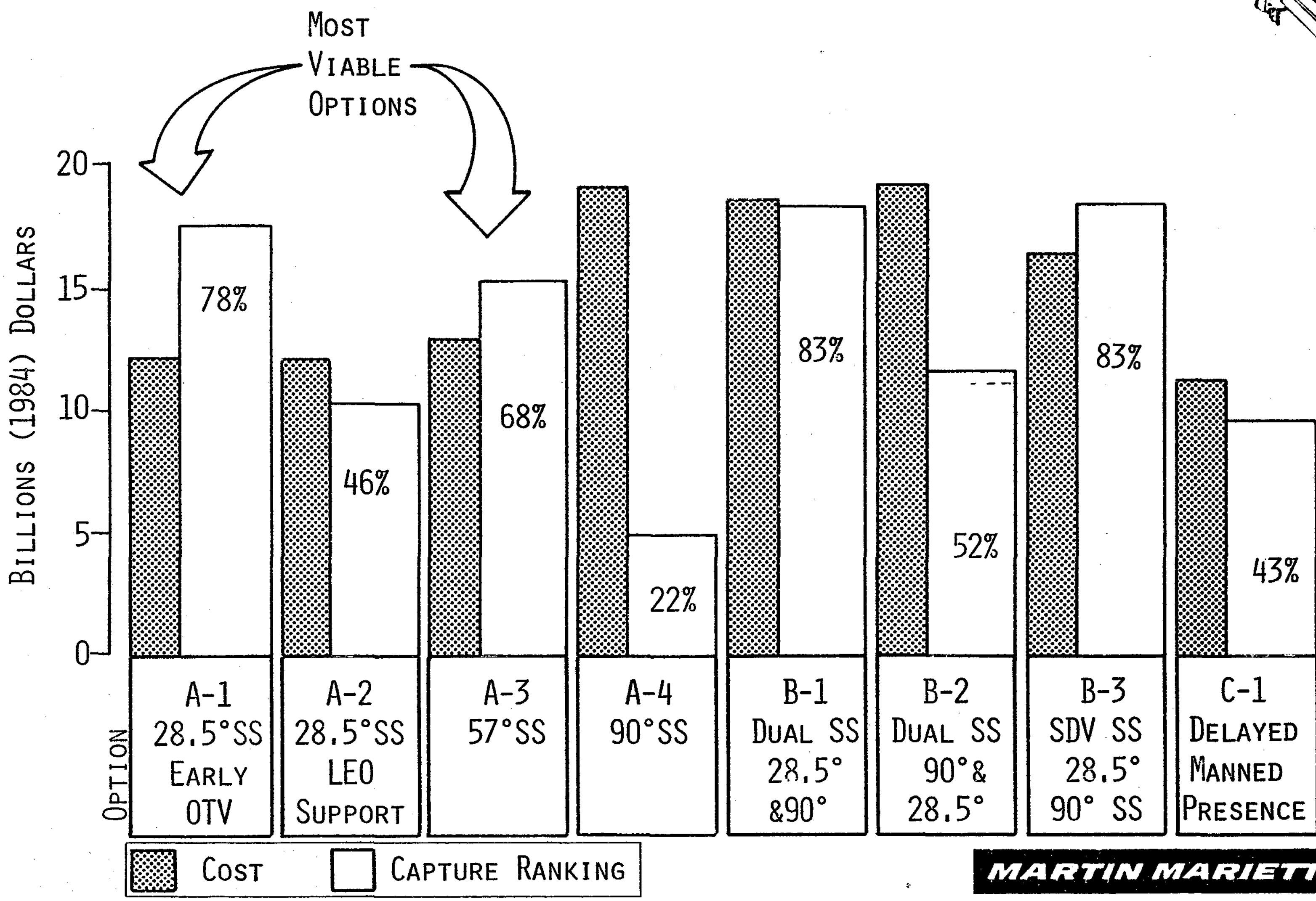
Program Option Selection





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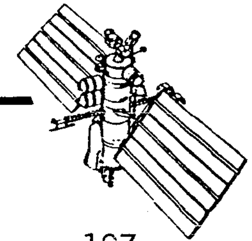
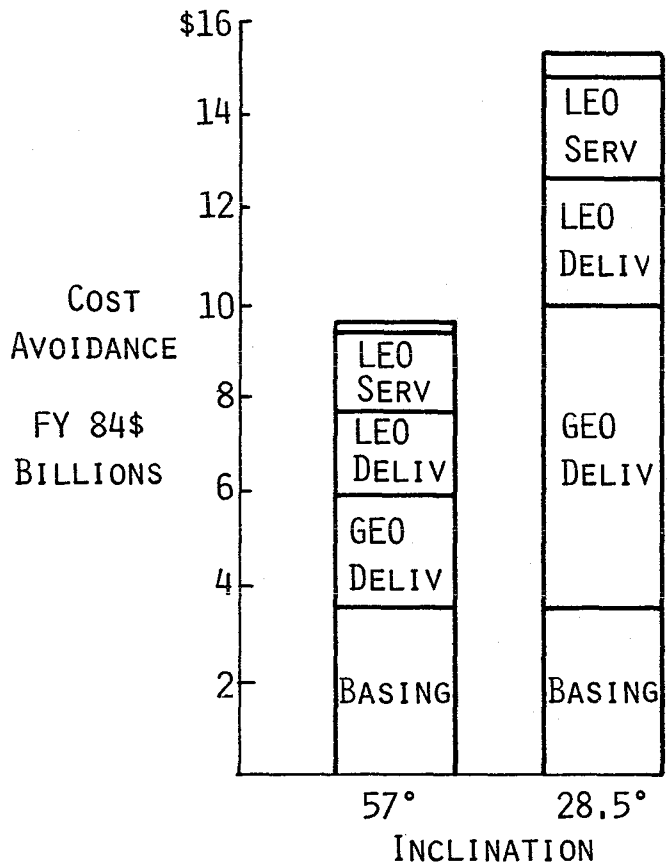
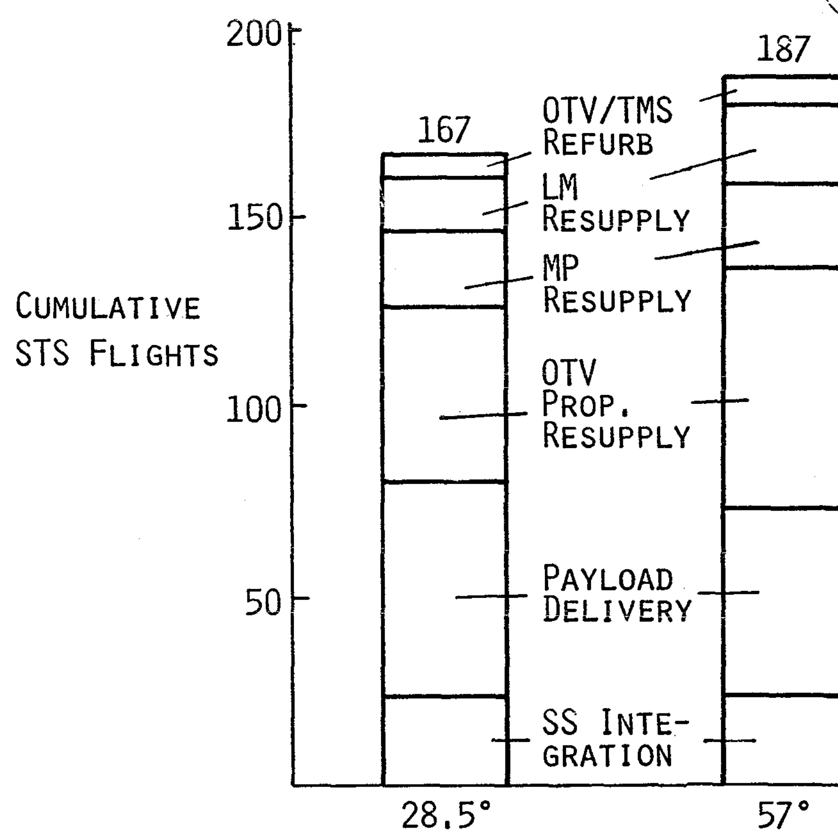
Economic Benefits & STS Support

Comparison of A–1 & A–3 Options

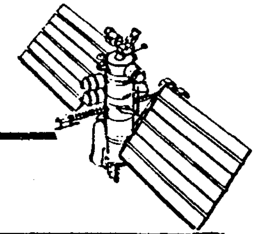




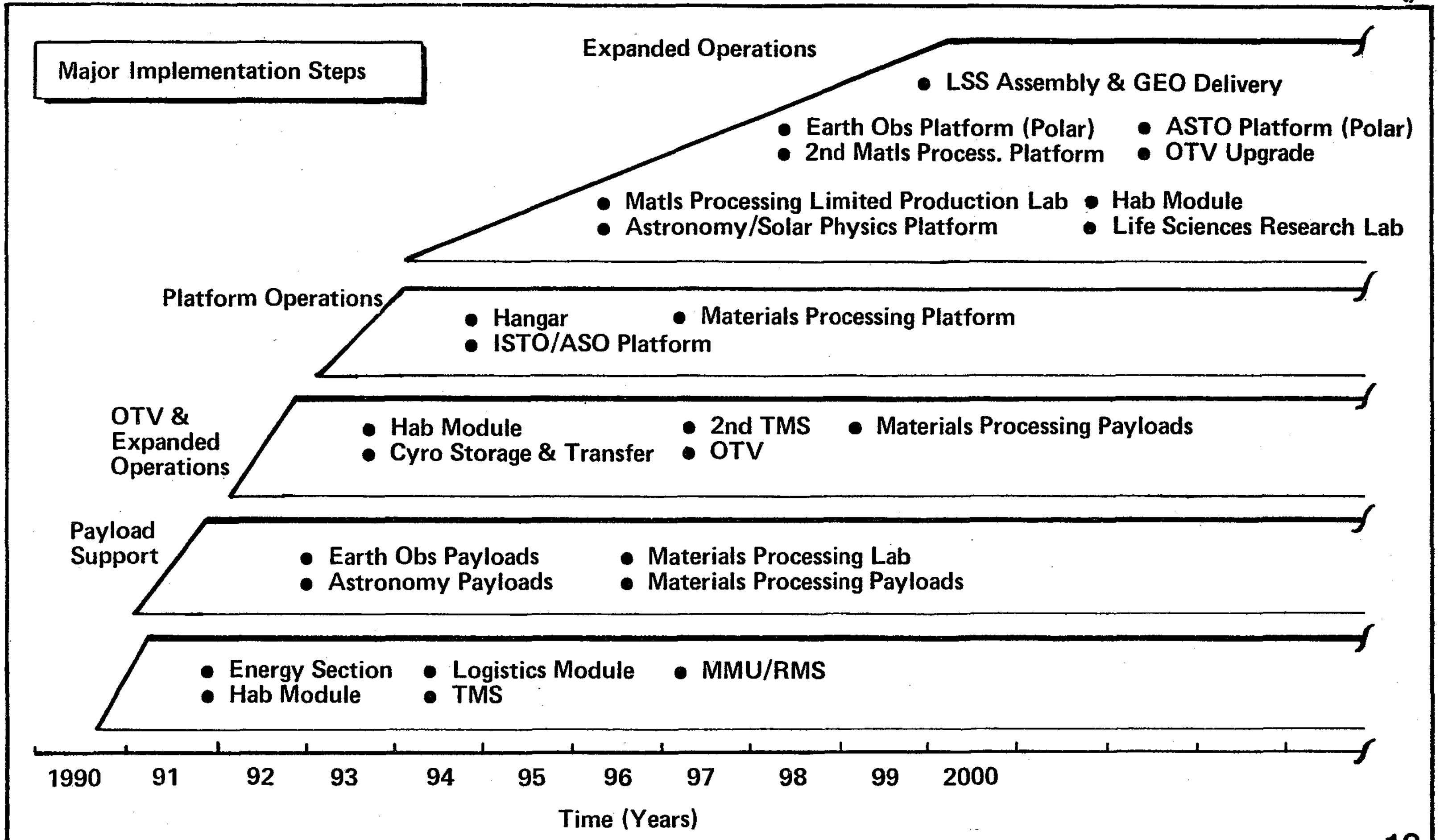


Economic Benefits
And STS Flights
Shown Are Cumulative
For 10 Years Of Operation

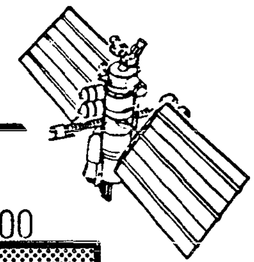
Recommended Evolution Plan

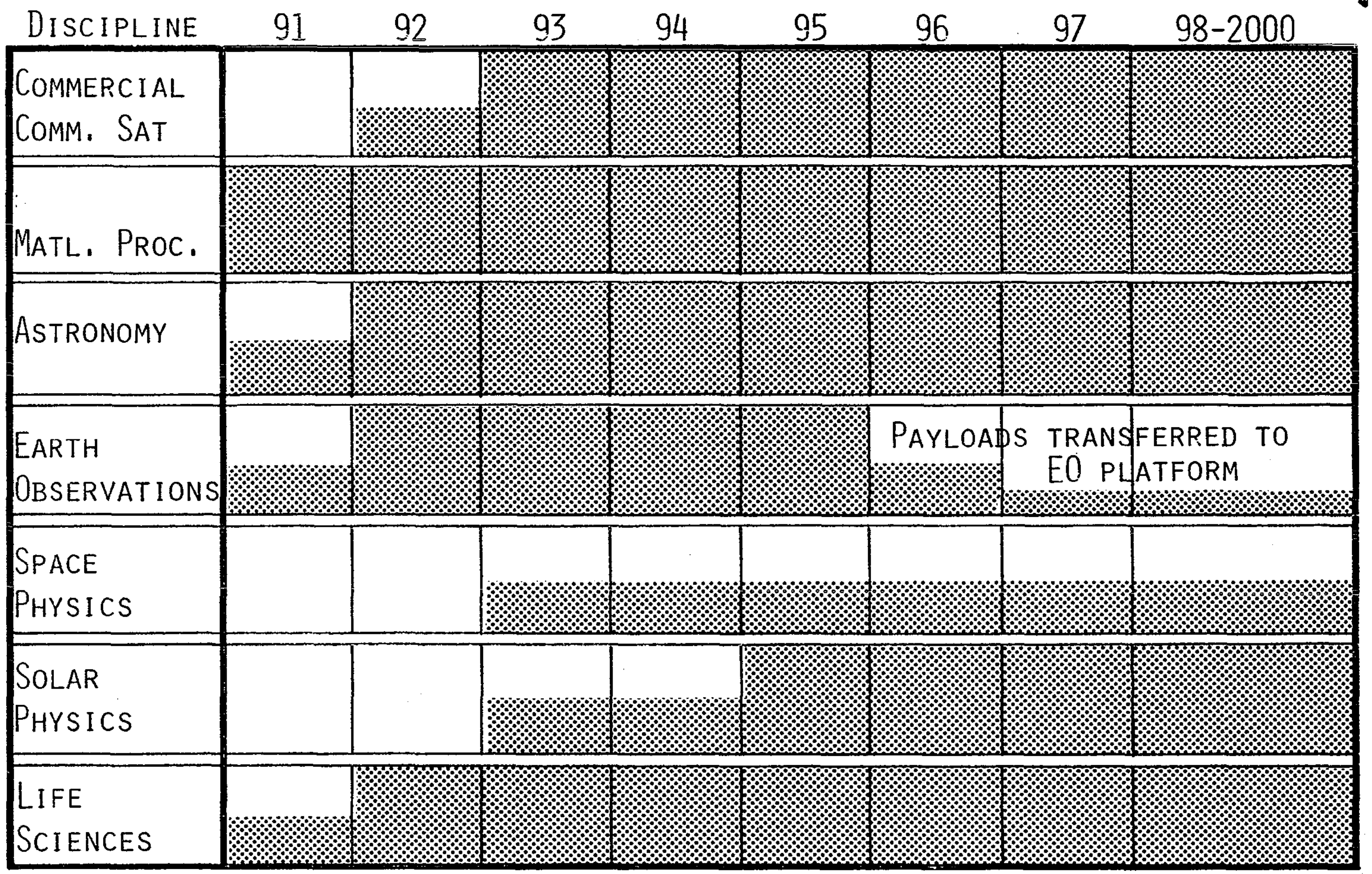


28.5° Space Station

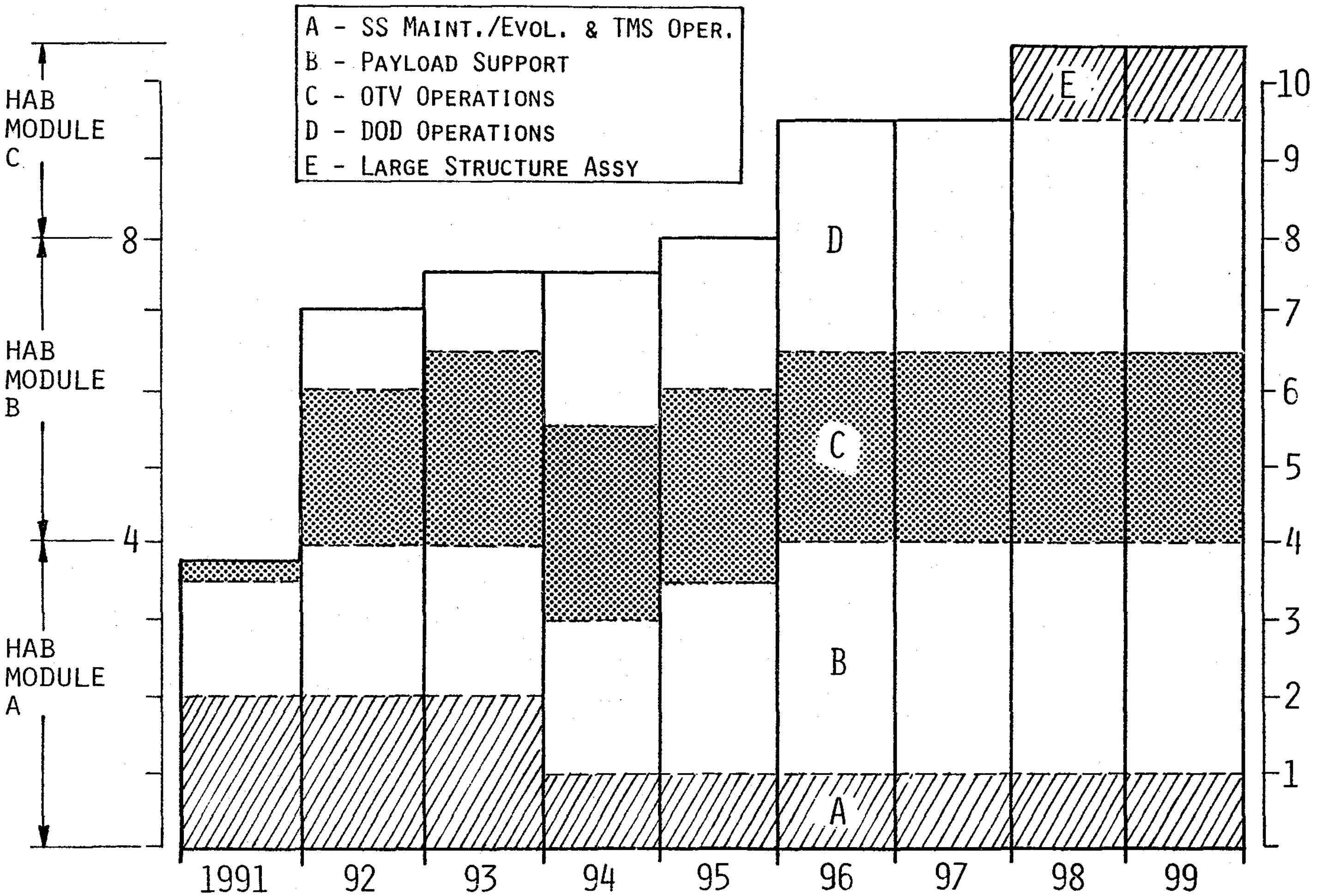


User Support Matrix





Crew Activities & Sizing



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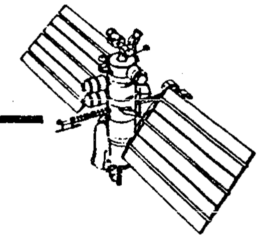
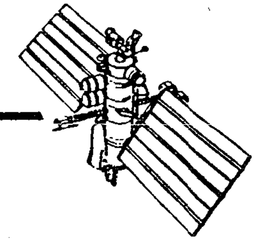


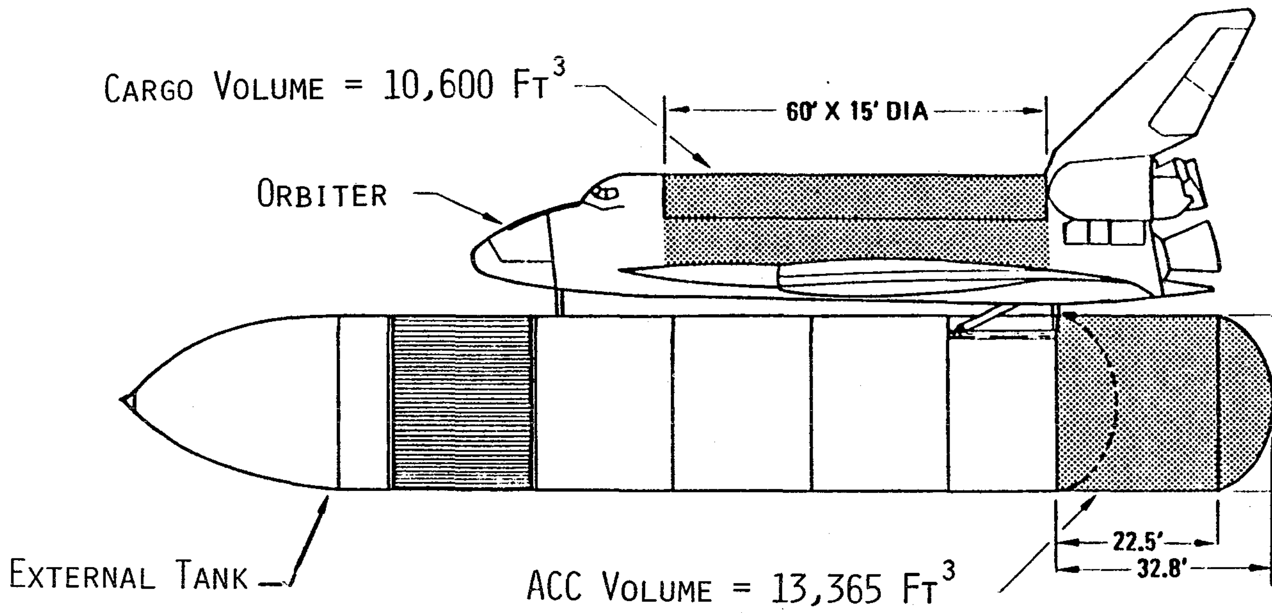
Space Station Architecture

Architectural/Configuration Options

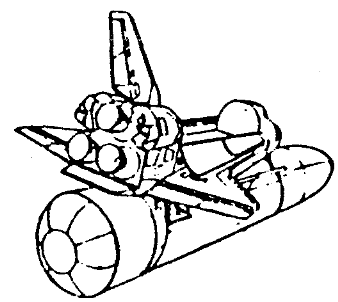
Option	Press. Volume	STS Flights	Advantages	Disadvantages
Modular 14' Dia.	23,700 FT^3	12	• Module Commonality • Favorable Mass Properties	• Complex Build-Up • Array Shadowing
Modular Aft Cargo Carrier	30,500 FT^3	10	• Utilizes Aft Cargo Carrier (ACC) Volume	• Complex Build-Up
Shuttle Derived Vehicle	33,000 FT^3	8	• Reduced Orbital Build-Up • Crew Safety & Comfort	• Development costs

ACC Launch Configuration





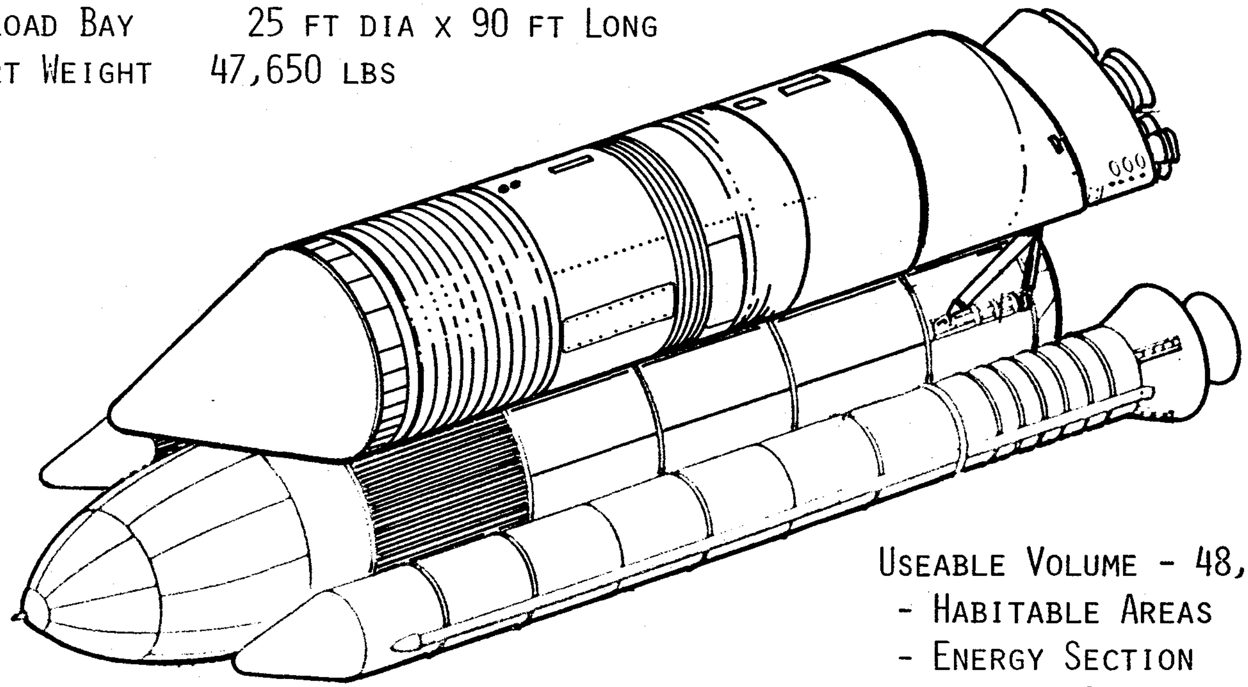
- Provides an Increase in Payload Diameter
- Provides Additional Volume
- Reduces Constraints on Payload Bay Limitations



SDV Launch Configuration

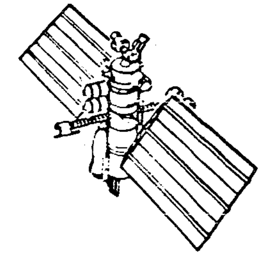
<u>Payload Module</u>

Overall Length	162.0 ft
Diameter	27.6 ft
Payload Bay	25 ft dia x 90 ft Long
Inert Weight	47,650 lbs

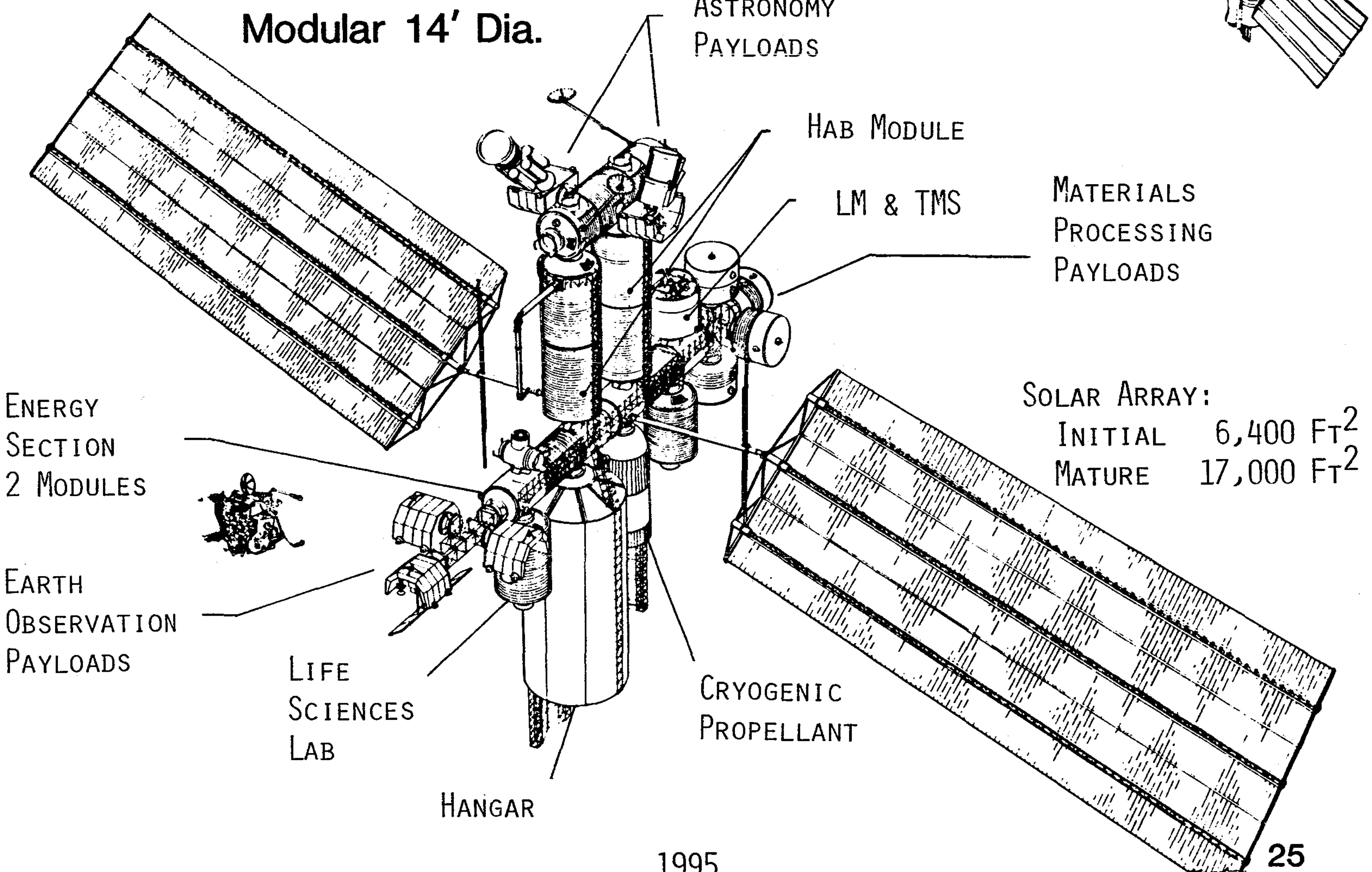


Useable Volume - 48,000 ft
- Habitable Areas
- Energy Section
- Hangar (Partial)
- Other Special Compartments

Mature Configuration (STS)



Modular 14′ Dia.



1995

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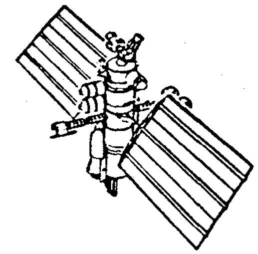
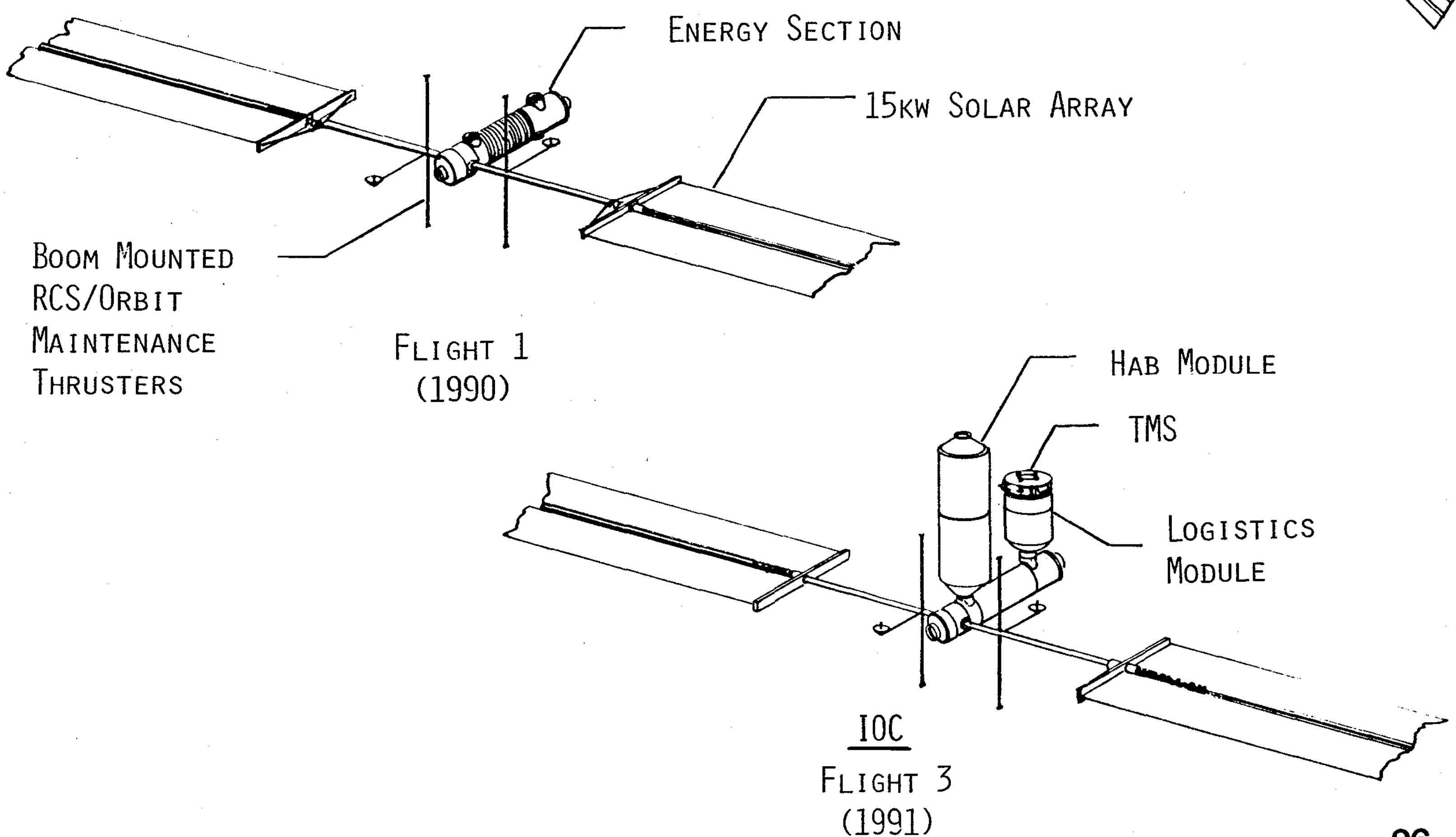
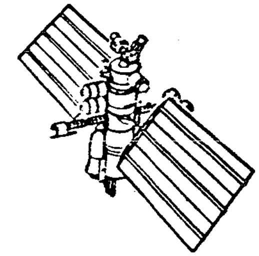
Early Configuration



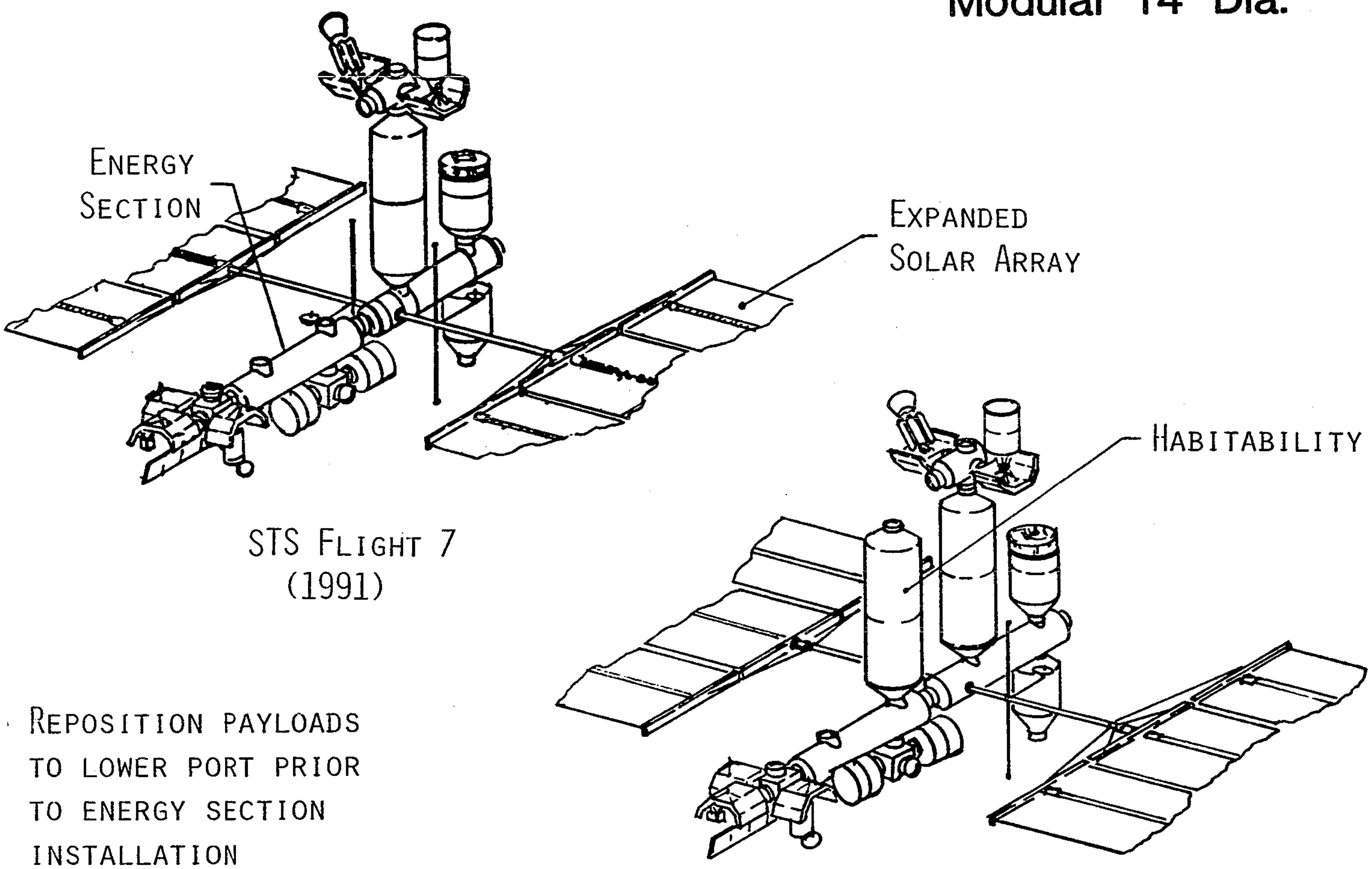
Modular 14′ Dia.



Intermediate Configuration



Modular 14′ Dia.



STS FLIGHT 7
(1991)

STS FLIGHT 8
(1992)

REPOSITION PAYLOADS TO LOWER PORT PRIOR TO ENERGY SECTION INSTALLATION

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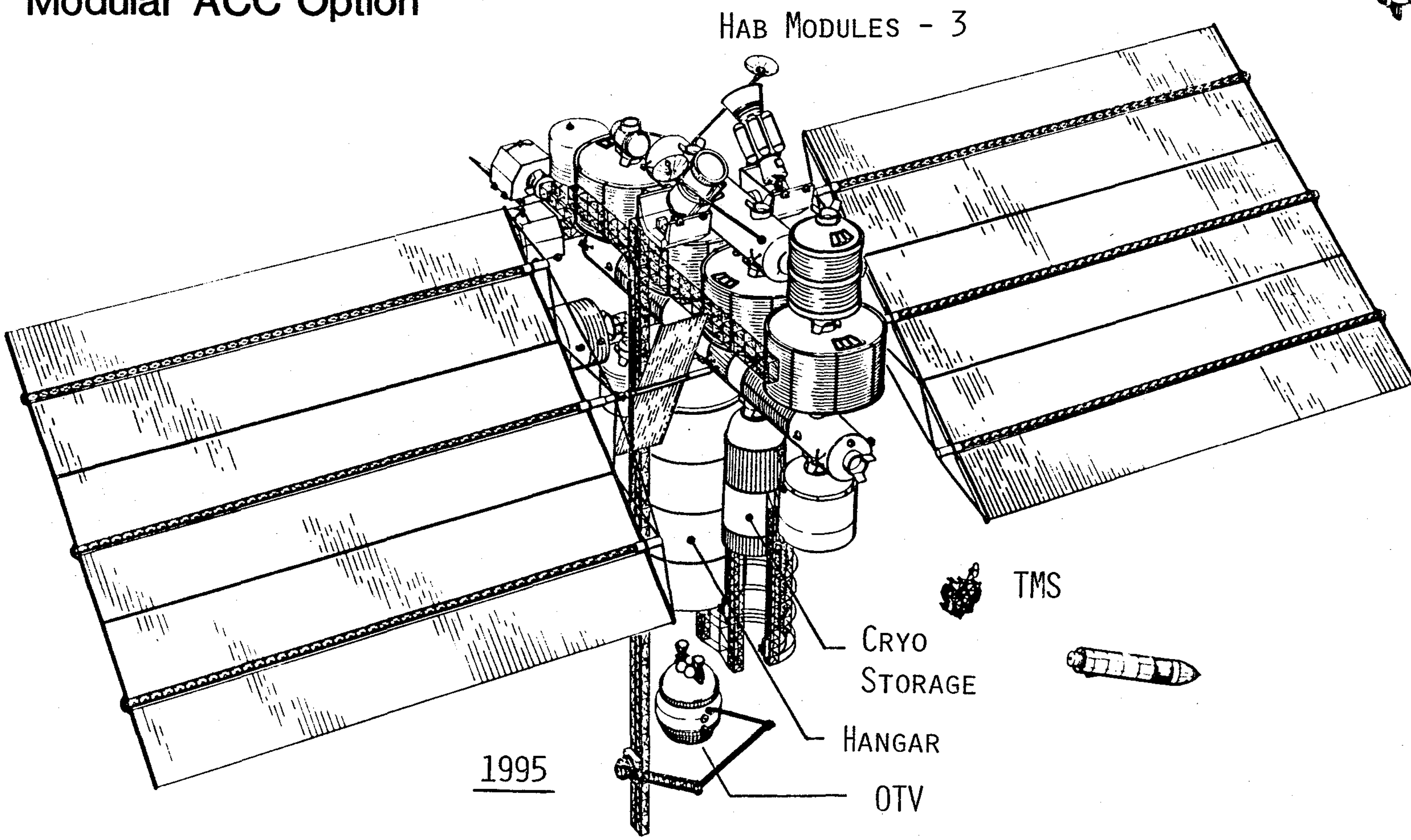
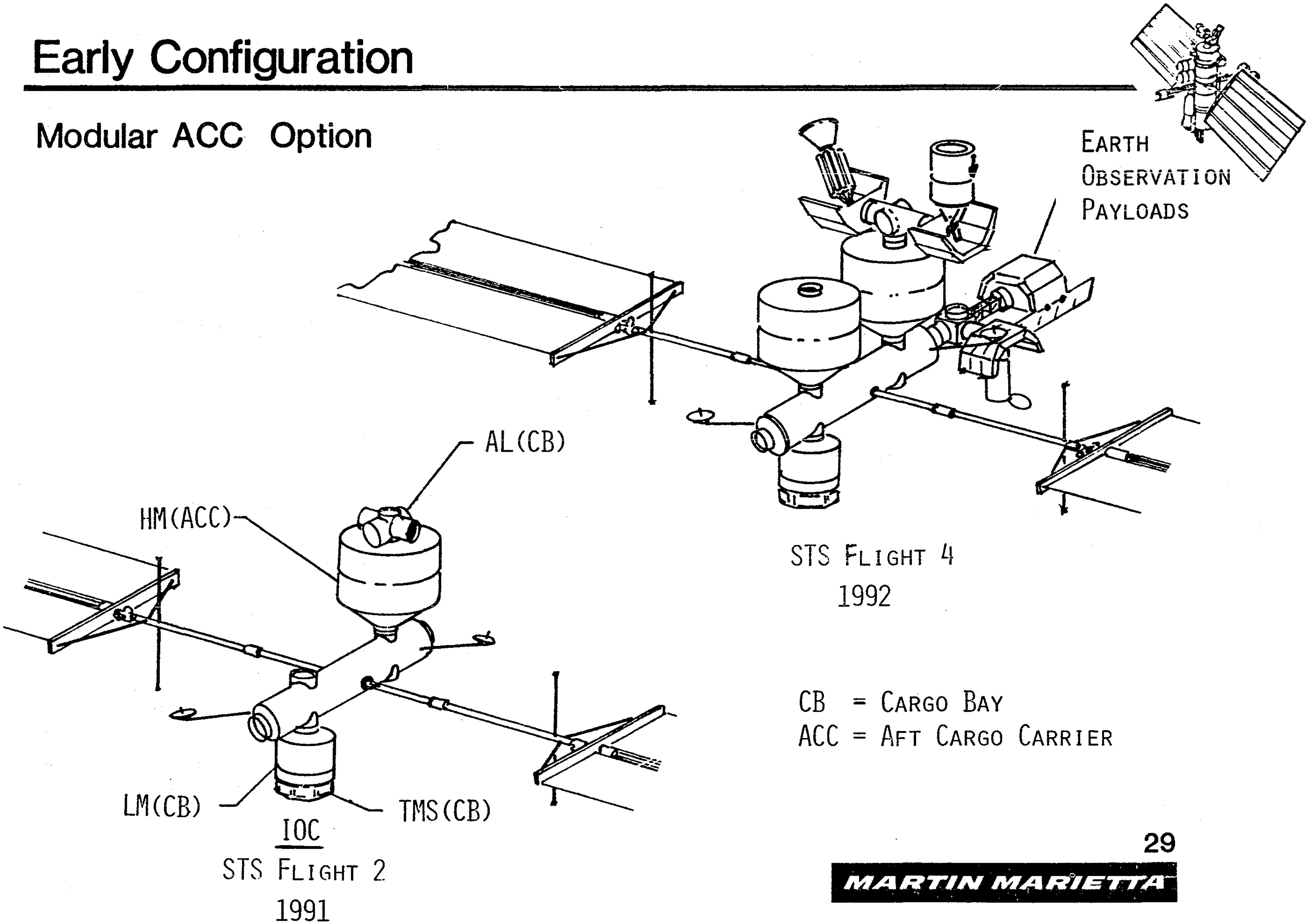
Mature Configuration (ACC)

Modular ACC Option



Early Configuration

Modular ACC Option



CB = CARGO BAY
ACC = AFT CARGO CARRIER

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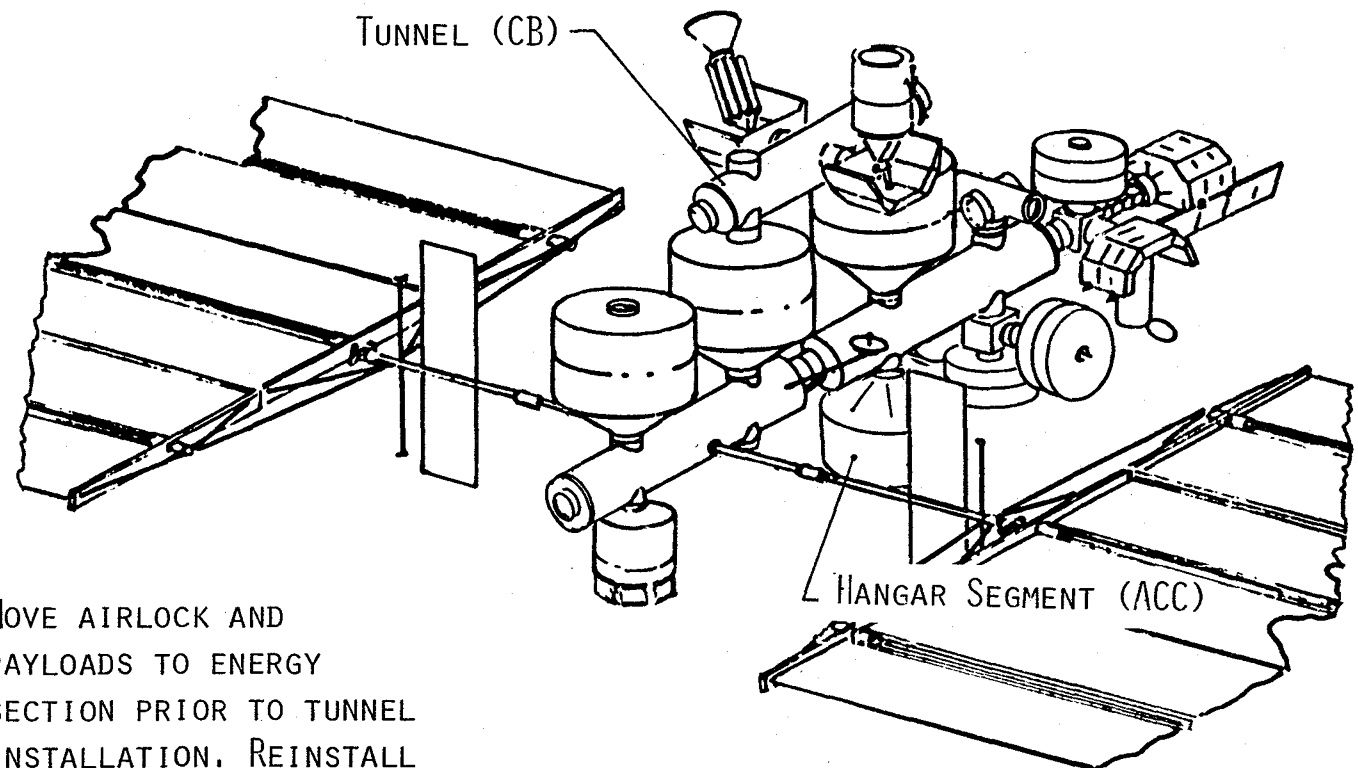
Intermediate Configuration

Modular ACC Option

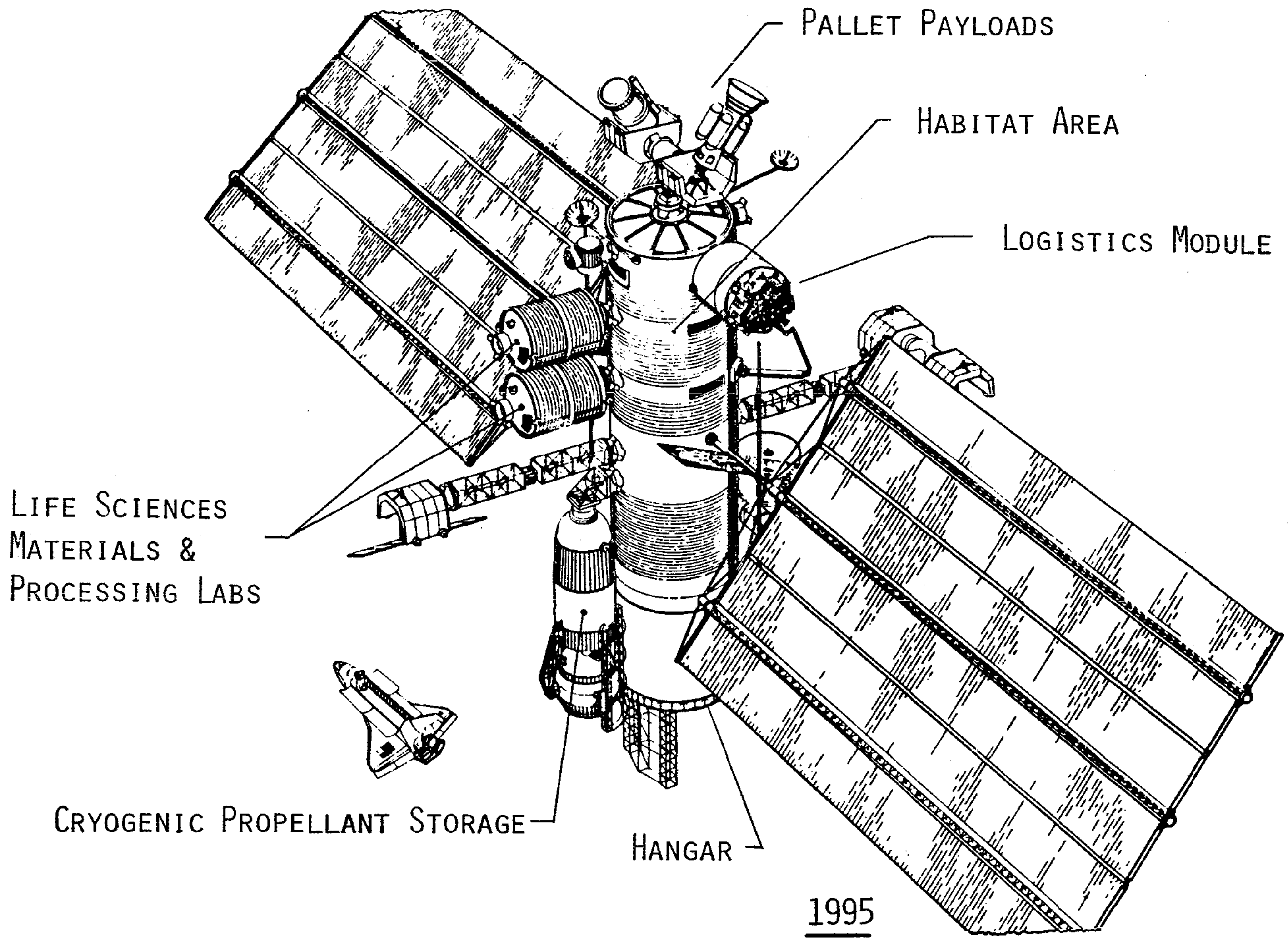


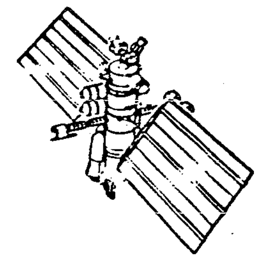
MOVE AIRLOCK AND PAYLOADS TO ENERGY SECTION PRIOR TO TUNNEL INSTALLATION. REINSTALL PAYLOADS ON TUNNEL MODULE

STS FLIGHT 7

1993

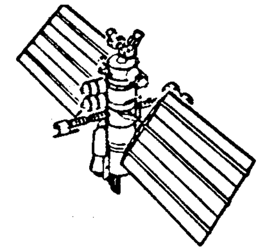
Mature SDV Configuration

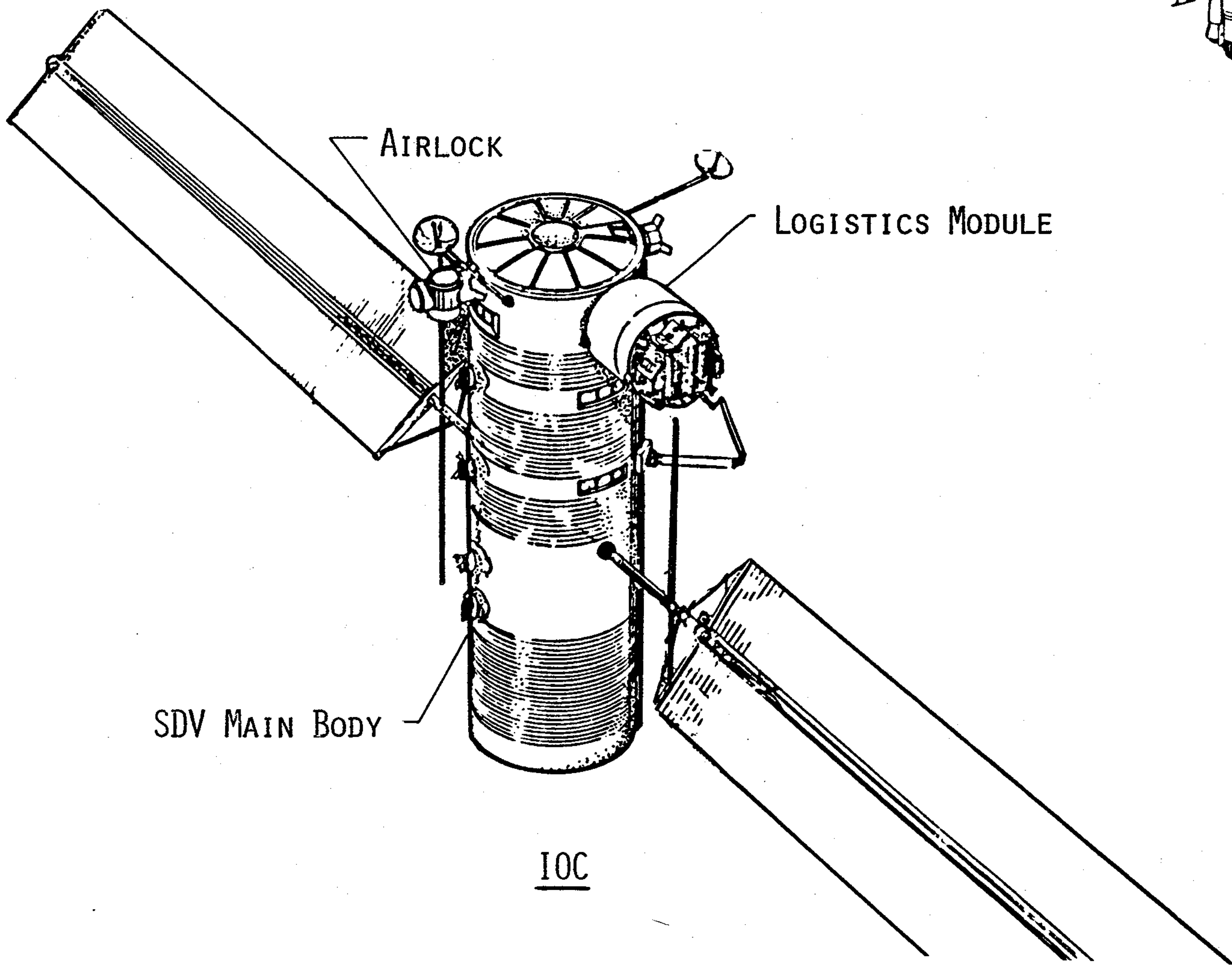




1995

Early SDV Configuration





IOC

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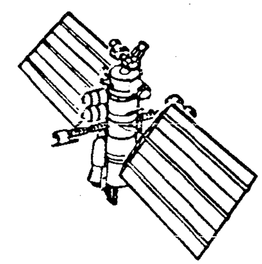
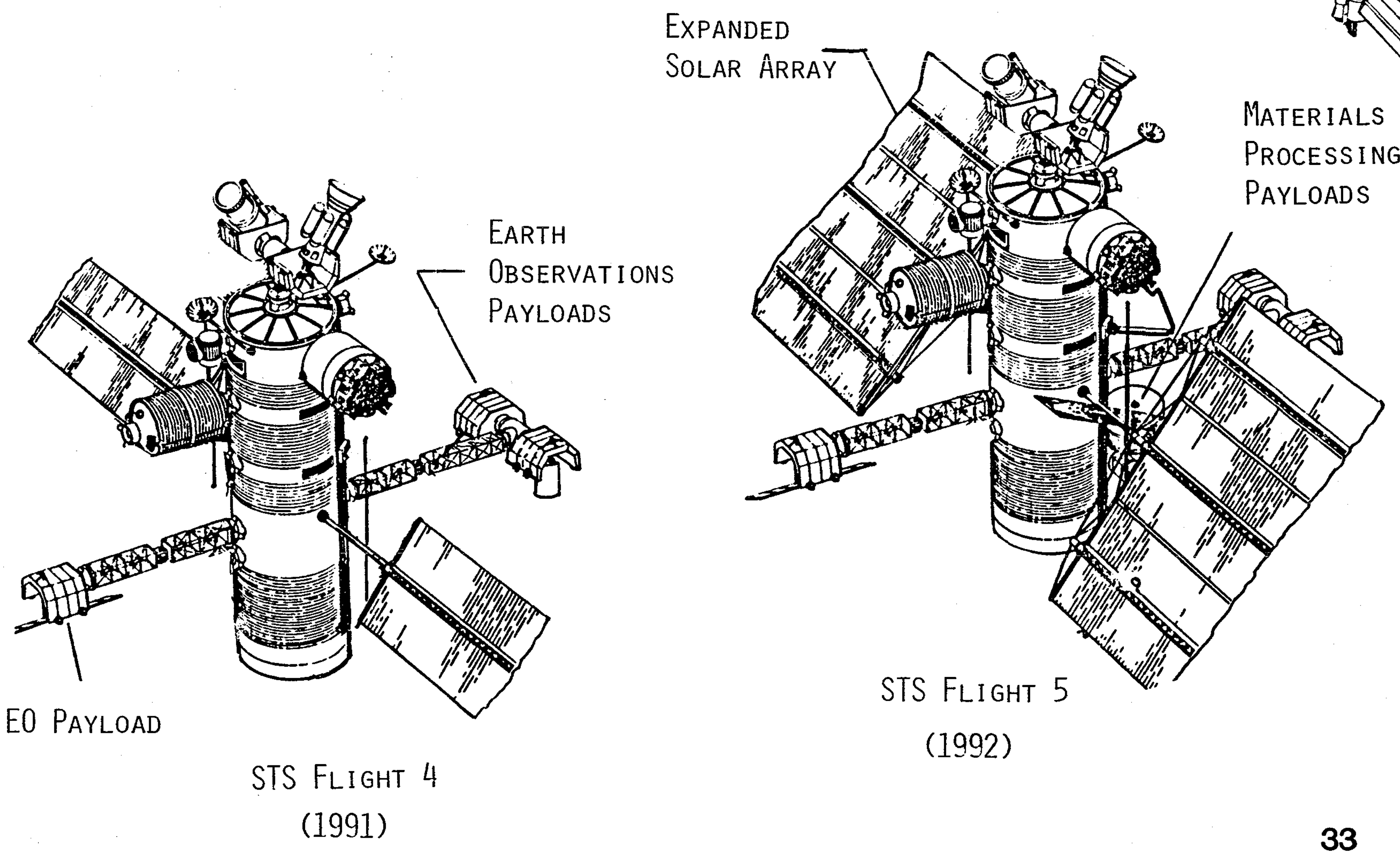
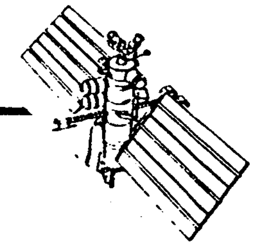
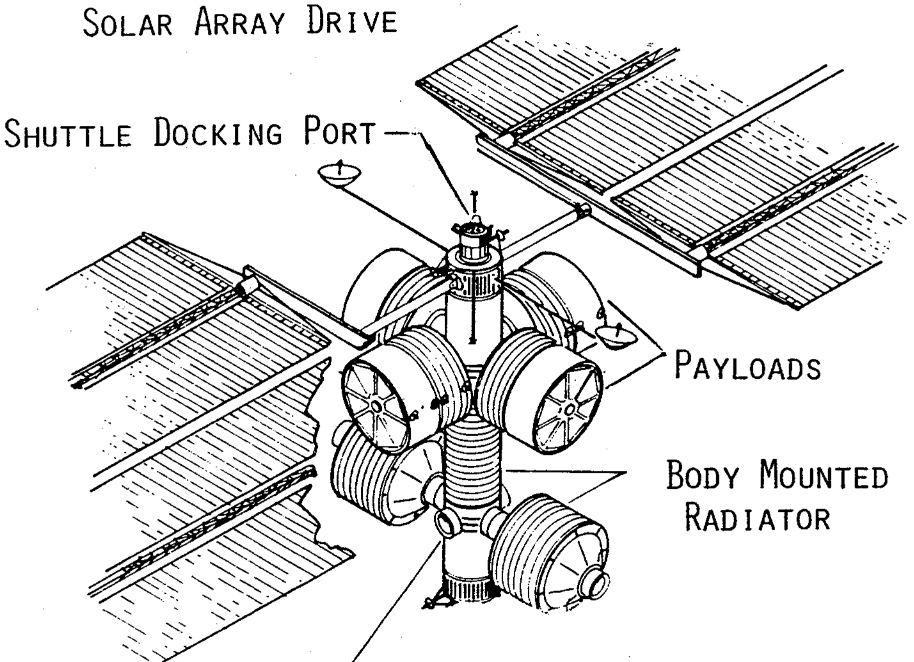
Intermediate SDV Configuration





Platform Approach





MATERIALS PROCESSING PLATFORM

- PLATFORM DESIGN EMPHASIZES COMMONALITY WITH SPACE STATION
  - ENERGY SECTION
  - SOLAR ARRAY
  - SUBSYSTEMS
- REDUCES ACQUISITION COSTS
- COMPONENT INTERCHANGEABILITY SIMPLIFIES SPARE PARTS LOGISTICS
- APPLICABLE TO ASTRONOMY PLATFORM

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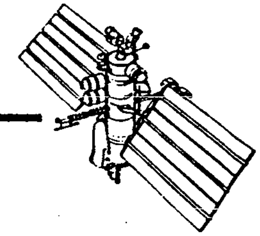
ETCLS Evolution



IOC 91 92 93 94 95 96 97 98 99 2000

Early ETCLS System

- RESUPPLY DRINKING WATER
- USE CONDENSATE FOR HYGIENE WATER
- REGENERABLE CO_2 REMOVAL

Intermediate ETCLS System

- LIMITED CLOTHES WASHING
- EVALUATE WASTEWATER PROCESSING

Mature ETCLS System

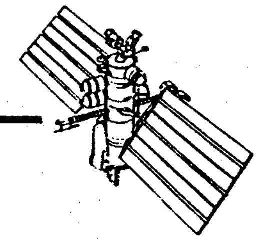
- CLOSED LOOP WATER & OXYGEN
- FULL HYGIENE CAPABILITY
- MINIMAL RESUPPLY

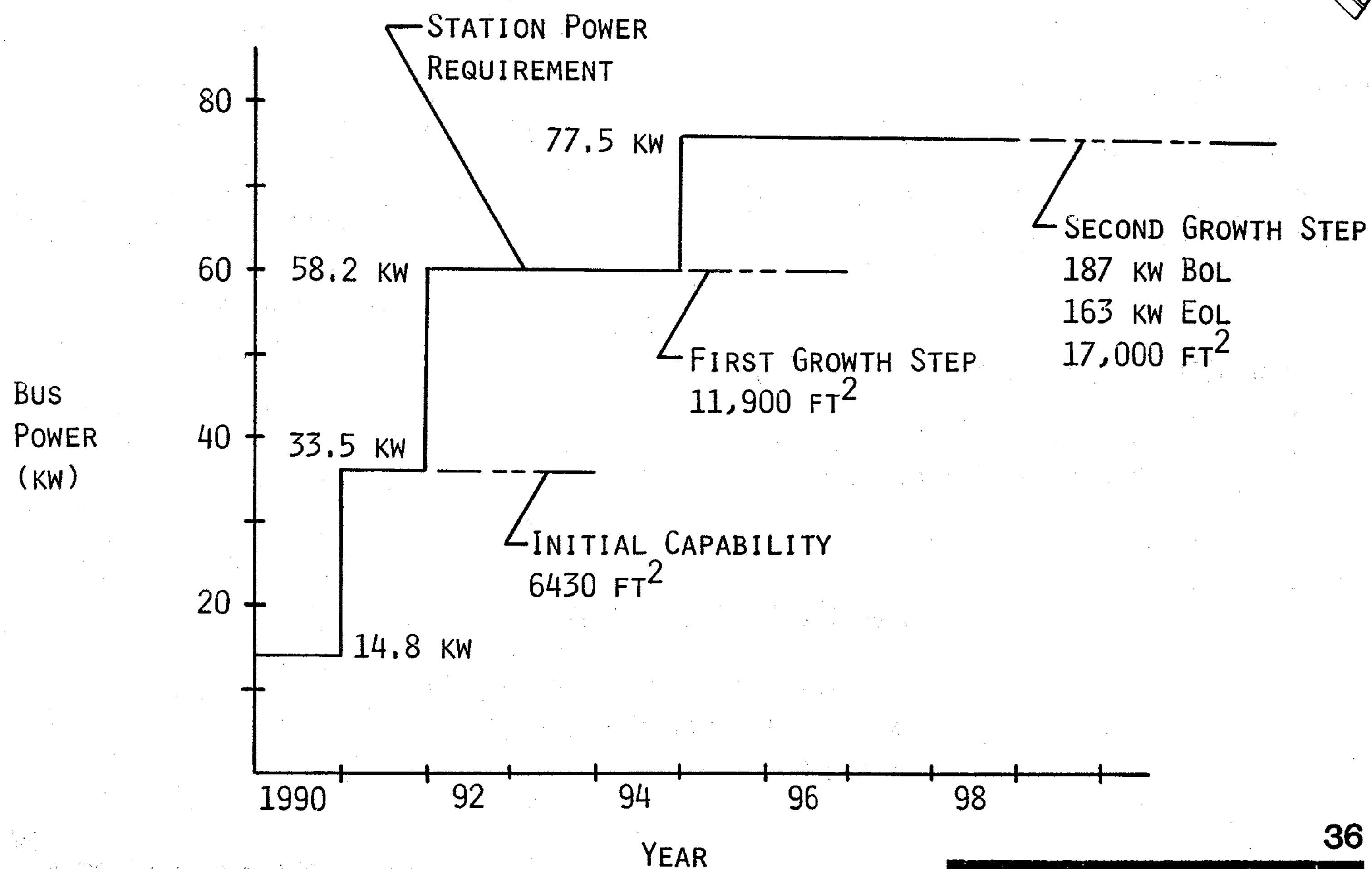
ETCLS —

Environmental Thermal Control

& Life Support

Power Requirements Growth





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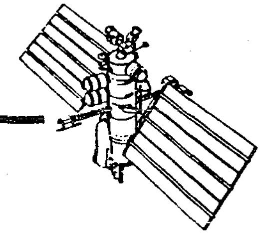
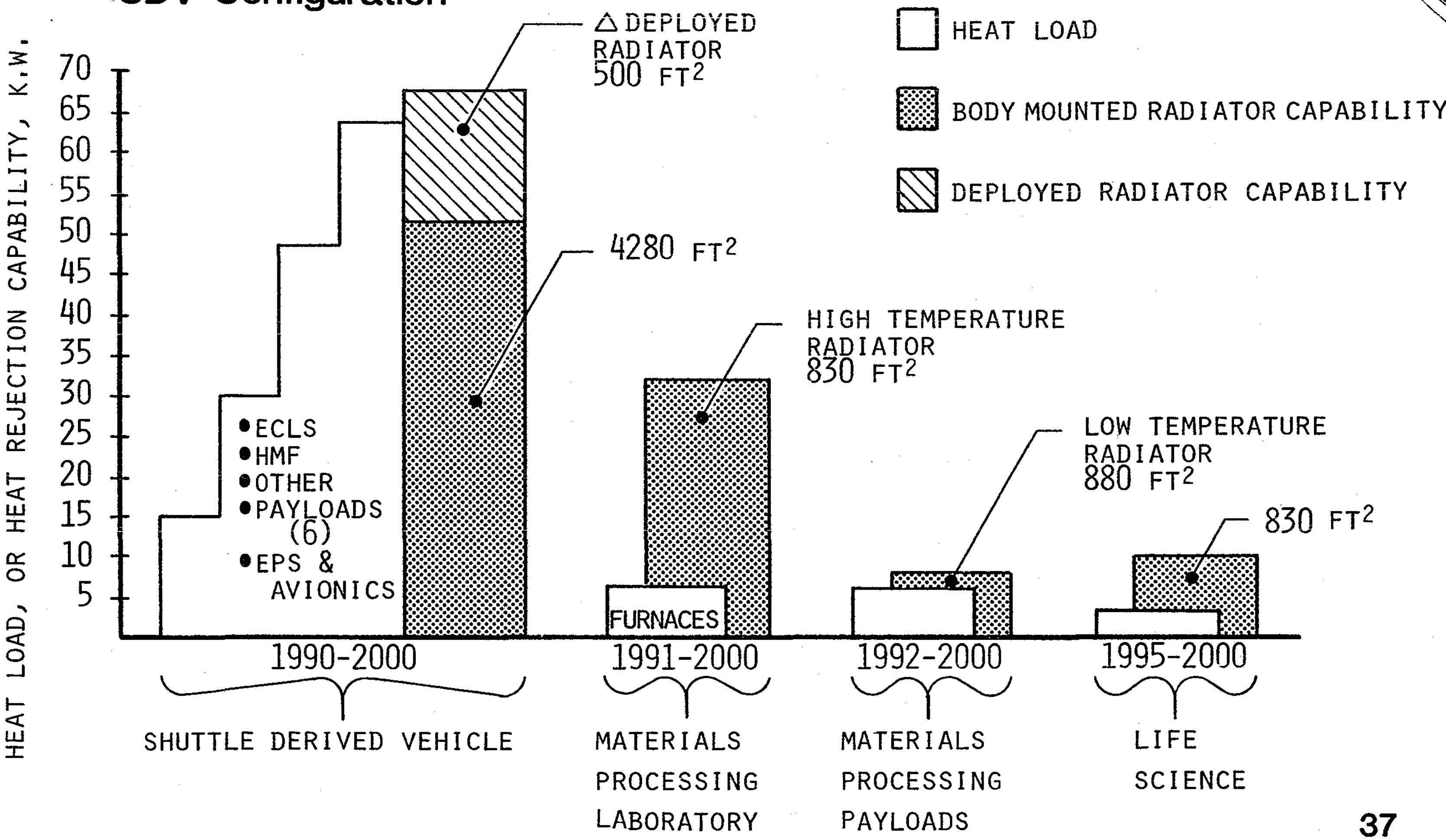
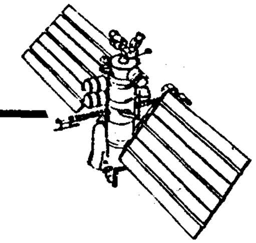
Heat Rejection Capability

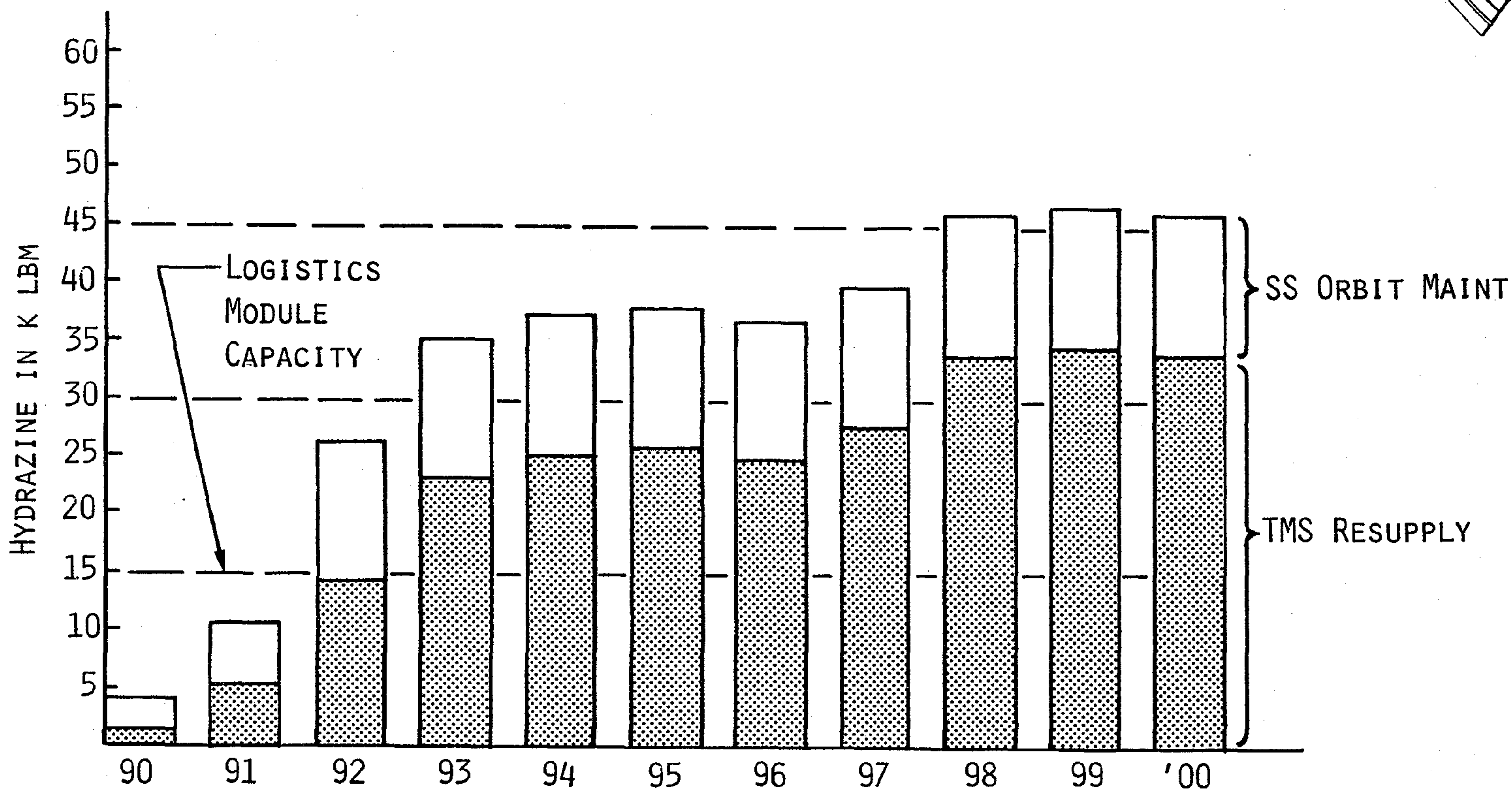


SDV Configuration



Hydrazine Usage





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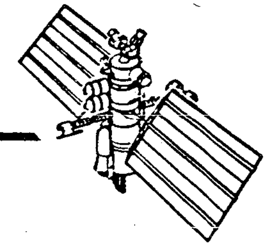
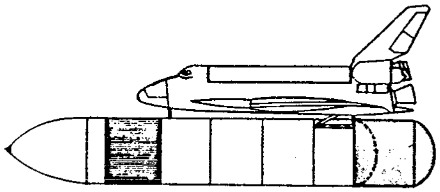
ET Scavenging Concept Feasibility



SUMMARY

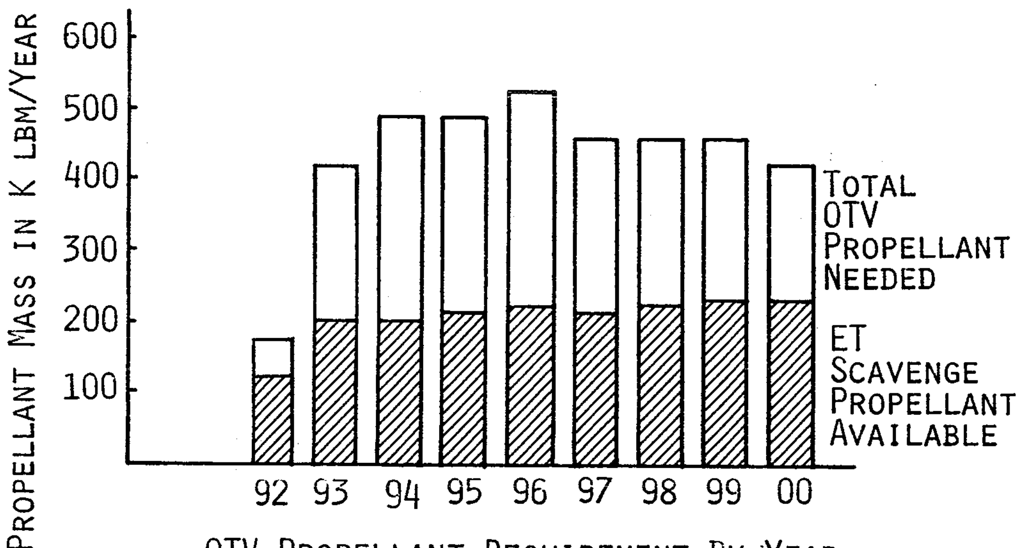
- SIGNIFICANT BENEFITS
- TECHNICALLY FEASIBLE
- NASA/MMC STUDIES



BENEFITS

- 9000 LBS PROPELLANT AVAILABLE FOR SCAVENGING
- ESTIMATED SAVINGS 2-4 STS FLIGHTS PER YEAR (6-9%) 1994-2000
- MANIFESTING ET PROPELLANT PAYLOAD WITH VOLUME LIMITED STS PAYLOADS INCREASES PROPELLANTS AVAILABLE AT SPACE STATION

REQUIREMENTS



OTV PROPELLANT REQUIREMENT BY YEAR

RELATED ACTIVITIES

IR&D

- MMC/MICHOUD-ET PROPELLANT UTILIZATION
- MMC/DENVER AEROSPACE-CRYOGENIC FLUID TECHNOLOGY

CONTRACTS

- MSFC/JSC-PROPELLANT SCAVENGING (NEAR-TERM RFP)
  - JOINTLY COORDINATED AND FUNDED ET SCAVENGING-CARGO BAY AND ACC
- LeRC-CRYOGEN FLUID MANAGEMENT FACILITY (CFMF)
  - DETAILED DESIGN OF FLIGHT READY CFMF
  - THERMAL/FLUID DYNAMICS-CRYOGENCS IN SPACE

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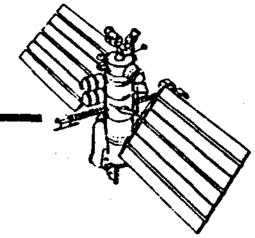
Subsystem Concepts



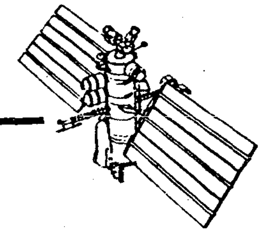
Propulsion

- Hydrazine used for SS orbit maintenance and attitude control
  - Uses 8 boom-mounted 30 lb thrusters
- Hydrazine storage (15000 lbs) in logistics module
- Inter-module hydrazine transfer capability
- Cryogen storage of 70000 lbs provided to resupply OTV

Attitude Control

- Gravity gradient attitude control of pitch and roll axes
  - Provides coarse stabilization
- Fine pointing provided separately for payloads
- Early configuration may augment RCS with CMGs
- Orbital rate (pitch axis) provides gyroscopic stabilization in yaw and roll axes

Subsystem Concepts (Cont.)



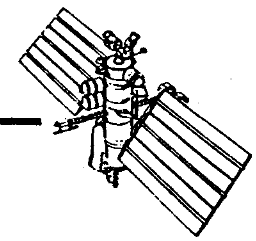
Data Processing

- DISTRIBUTED ARCHITECTURE
- END-TO-END SYSTEM INTERFACING SS DATA BUS WITH GROUND PROCESSORS
- ESTIMATE DATA STORAGE IN THE RANGE OF

  1.2×10^{10} TO 1.2×10^{11} IS REQUIRED
- NEED EXISTS FOR SIGNIFICANT DATA REDUCTION OF USER DATA

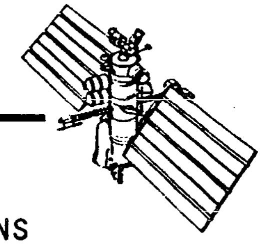
Communications

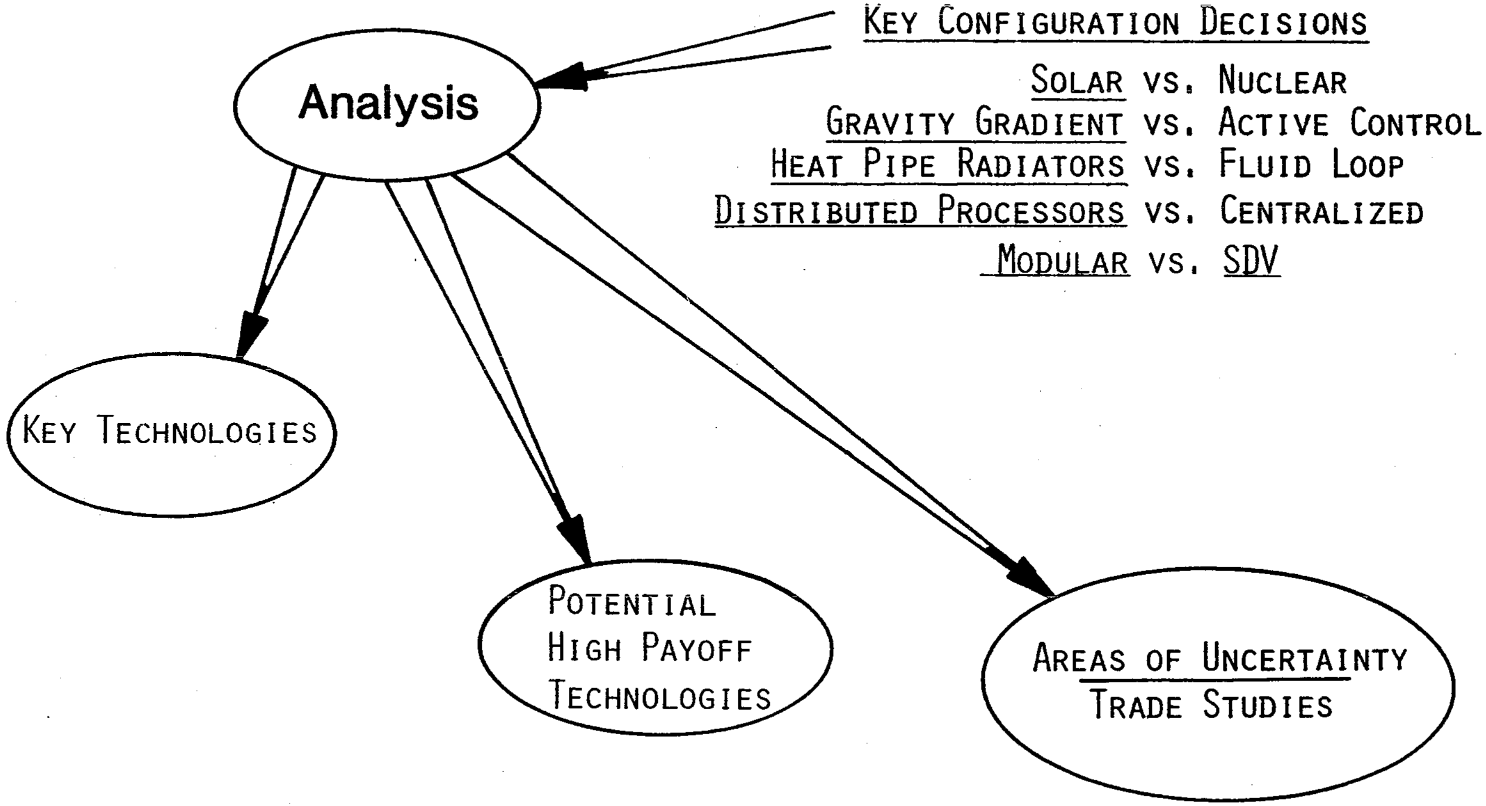
- NUMEROUS RF INTERFACES MAY REQUIRE OPERATIONS AT UHF, L, S & KU BANDS, AT 40-60 GHZ, AND AT LASER WAVELENGTH
- HIGH USER DATA RATES AND VOLUME DRIVES NEED FOR STORE & DUMP APPROACH
- DATA DUMPS AS FREQUENT AS EVERY ORBIT MAY BE NECESSARY
- RF LINKS MAINTAINED WITH CO-ORBITING PLATFORMS



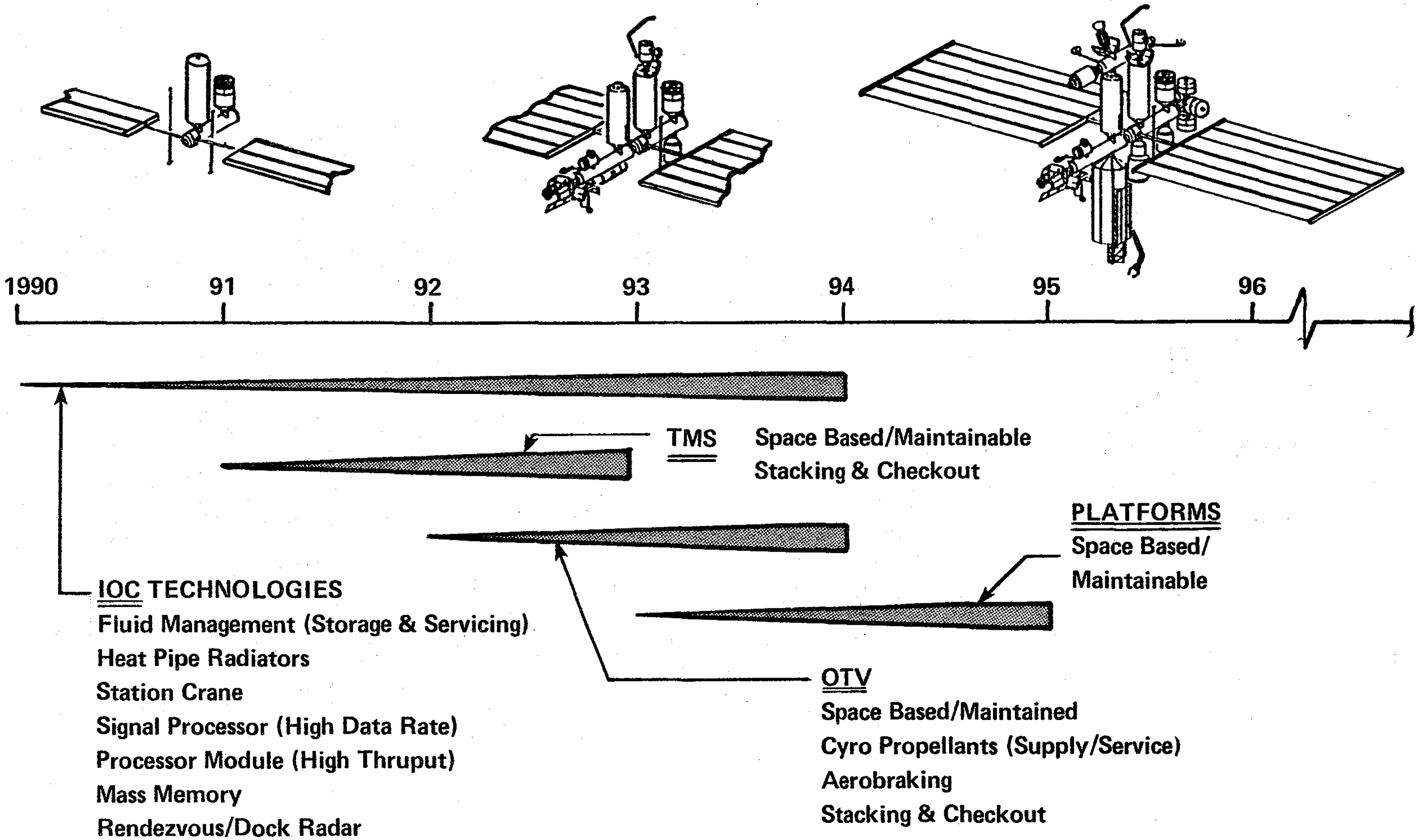
Key Technologies

Technology Assessment

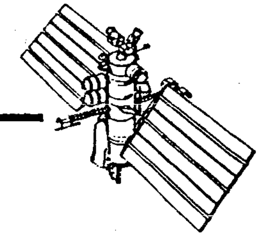




Key Technologies



Potential High Payoff Technologies



INCREASED EFFICIENCY SOLAR CELLS
(GAAS, THIN CELLS, MULTIBAND, CONCENTRATORS)
FUEL CELL/ELECTROLYSIS UNITS

CRYOGEN FUELED TMS
ET PROPELLANT SCAVENGING
ELECTRIC THRUSTERS

TWO PHASE ISOTHERMAL HEAT TRANSFER SYSTEM
CONTACT HEAT EXCHANGERS

TETHER UTILIZATION

Areas Of Uncertainty – Analyses & Trades

Operations

- Control Authority Allocations
- Control Stations
- Contamination Control

Architecture

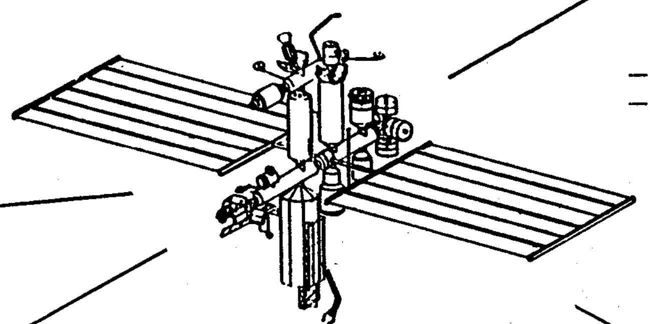
- Subsystem Modularity
- Pressure Levels (STS, Station, EVA)
- Debris Collision Shielding vs Damage Control

Crew

- Crew Utilization Criteria (Timelines, Skills, Health, Rotation, Training,)
- ECLS Commodities Reuse

Power

- Silicon vs Gallium Arsenide
- NiH_2 Batteries vs Regenerative Fuel Cells



Communications

- RF Interfaces Analysis

Mechanisms

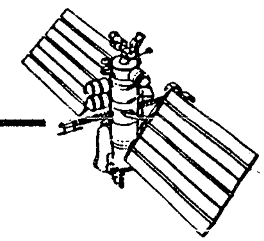
- Station Crane Concept

Data Management

- Mass Memory Storage Medium
- Data Bus - Fiber Optic vs Coax
- Data Bus User Protocol

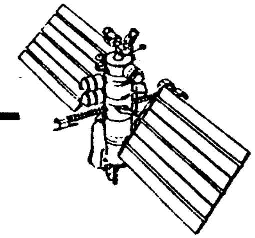
Propulsion

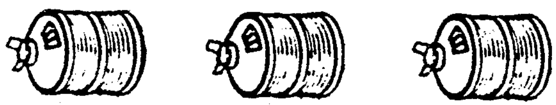
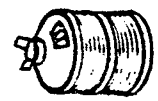
- Common Cryogen Fuel vs Conventional Fuels
- Cryogen Resupply (Dedicated, ET Scavenge, Topping)
- Electric vs Chemical Thrusters
- Mass Monitoring (Storage & Transfer)



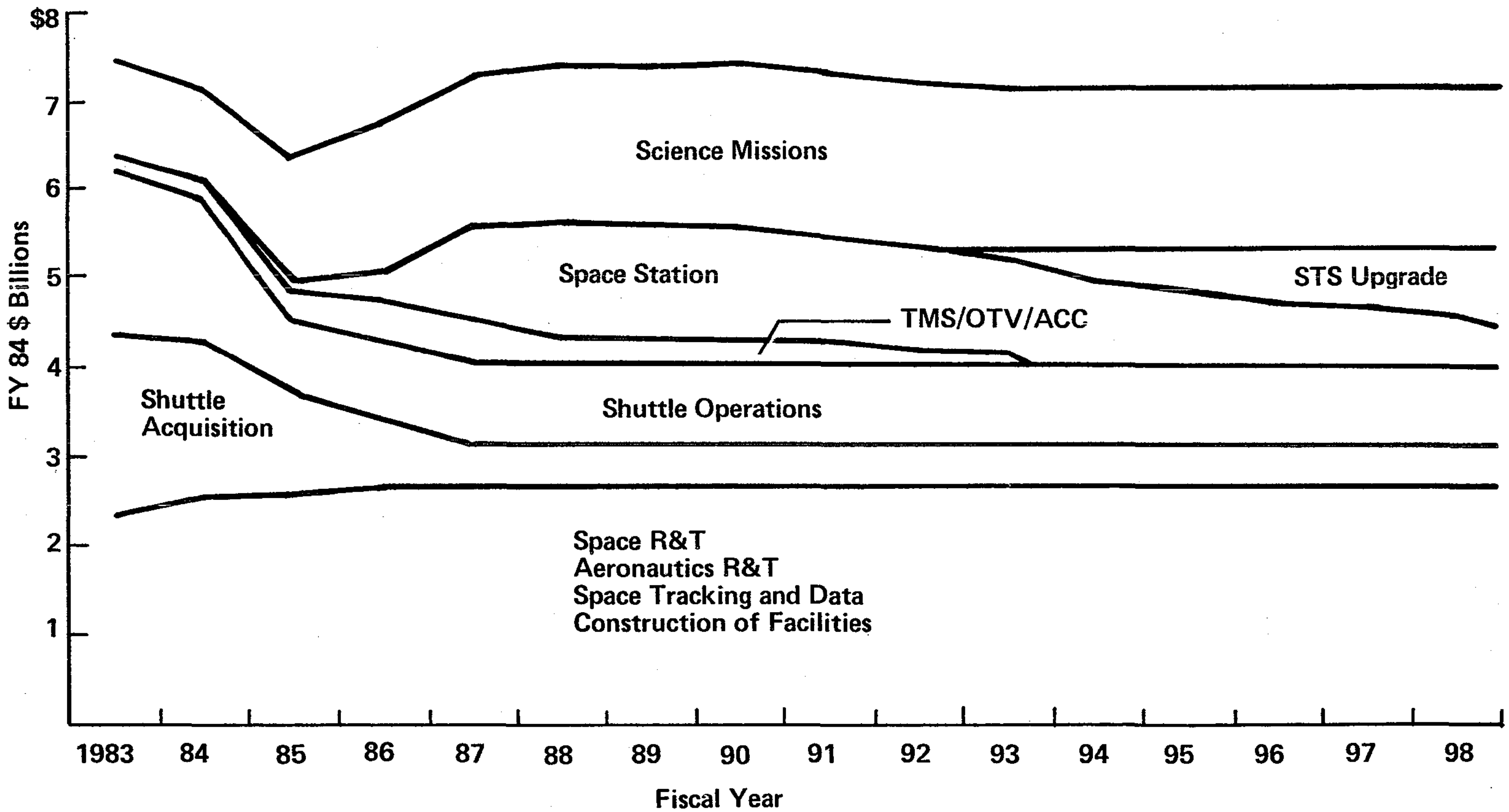
Associated Cost and Benefits

Programmatic Approach To Low Cost Space Station

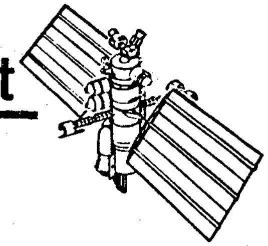


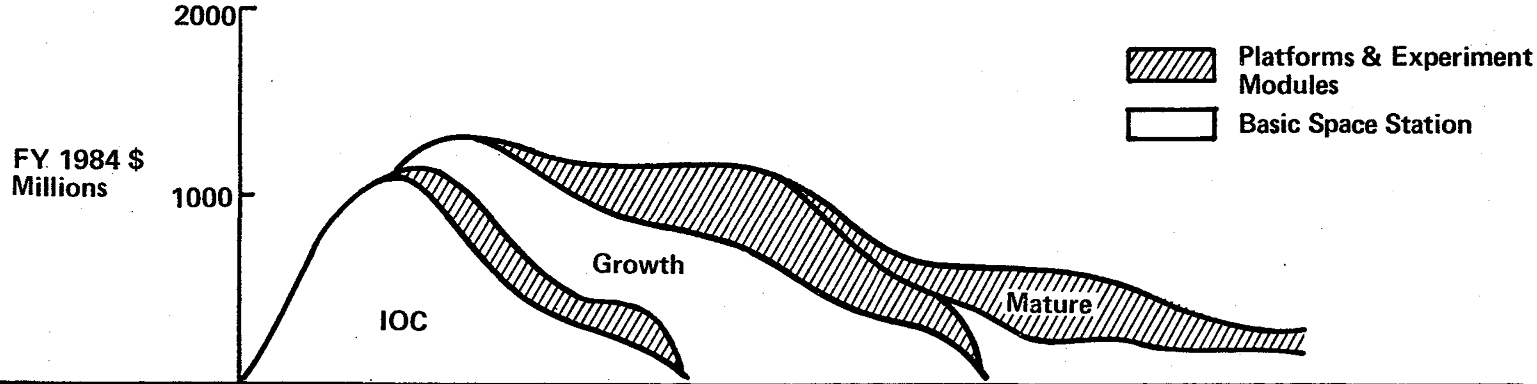
Traditional Approach		Space Station Approach
 Qual. Backup Flight	Number of Units	 Protoflight
Small Modules Resulting in High Cost per Pound	Size of Modules	STS Capability Permits Large Modules with Economy of Scale
Intensive Ground Support	Mode of Operation	Autonomous Operation Allows Significantly Reduced Gnd Mission Ops
Acquisition = \$100,000/lb Spacelab 35,000/lb Skylab Operation ≃ 10% Acq/Yr	Cost Estimating Relationships	Acquisition = \$20,000/lb Operation ≃ 3% Acq/Yr

NASA Budget Projection – Affordability Analysis



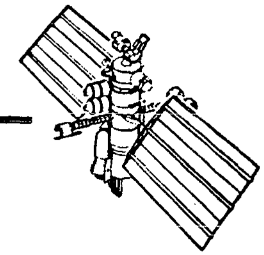
Space Station Costs By Phase – Modular Concept

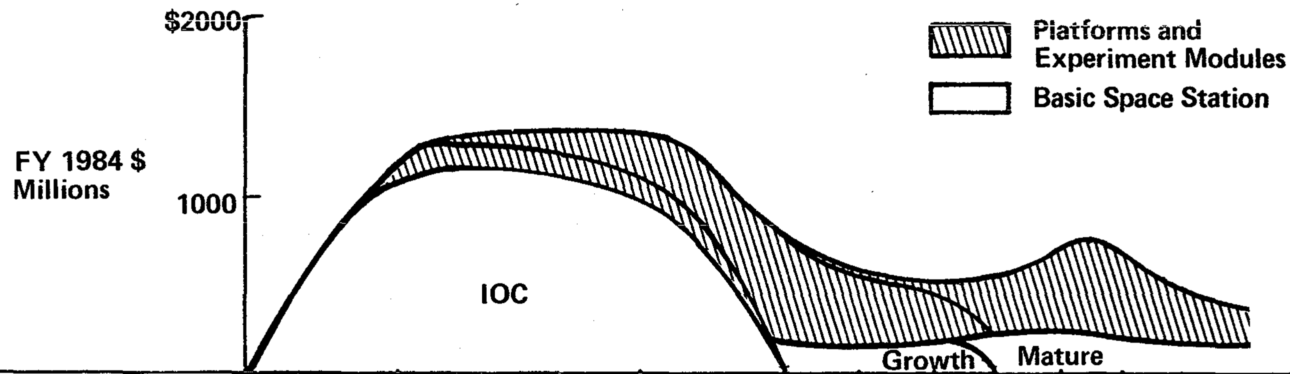




FY	1986	87	88	89	90	91	92	93	94	95	96	97	98	99	2000	Total	Cum Total
IOC Space Station	290	1020	1100	620	370	190										3,590	3,590
Platforms and Experiment Modules		10	80	170	95	225										580	580
Growth Space Station			110	470	620	480	800	565	400	365						3,810	7,400
Platforms and Experiment Modules				35	200	300	350	470	255	135						1,745	2,325
Mature Space Station										10	245	280	215	215	215	1,180	8,580
Platforms and Experiment Modules								40	130	210	325	270	230	95	70	1,370	3,695
Total	290	1030	1290	1295	1285	1195	1150	1075	785	720	570	550	445	310	285	12,275	12,275

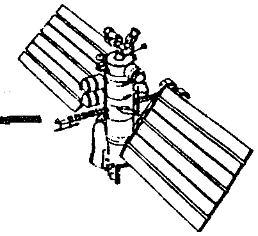
Space Station Costs By Phase – SDV Concept

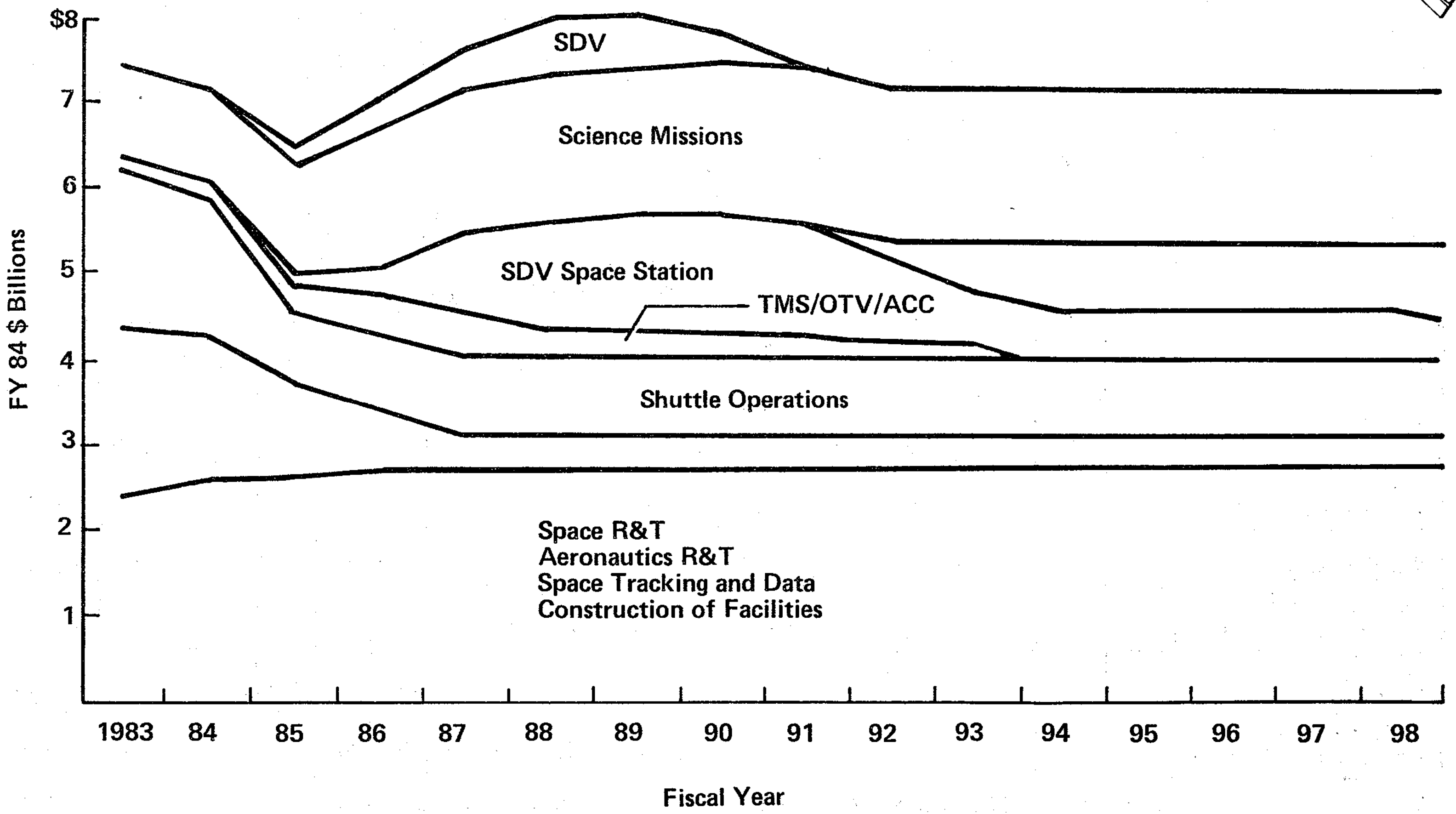




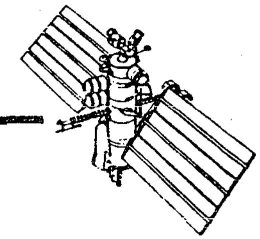
FY	1986	87	88	89	90	91	92	93	94	95	96	97	98	99	2000	Total	Cum Total
IOC Space Station	280	890	1175	1150	1065	990	465									6,015	6,015
Platforms and Experiment Modules		10	80	170	95	25	220									600	600
Growth Space Station								165	165	215						545	6,560
Platforms and Experiment Modules				45	200	280	235	450	270	135						1,615	2,215
Mature Space Station										10	245	280	215	215	215	1,180	7,740
Platforms and Experiment Modules								40	55	165	325	370	285	190	70	1,500	3,715
Total	280	900	1255	1365	1360	1295	920	655	490	525	570	650	500	405	285	11,455	11,455

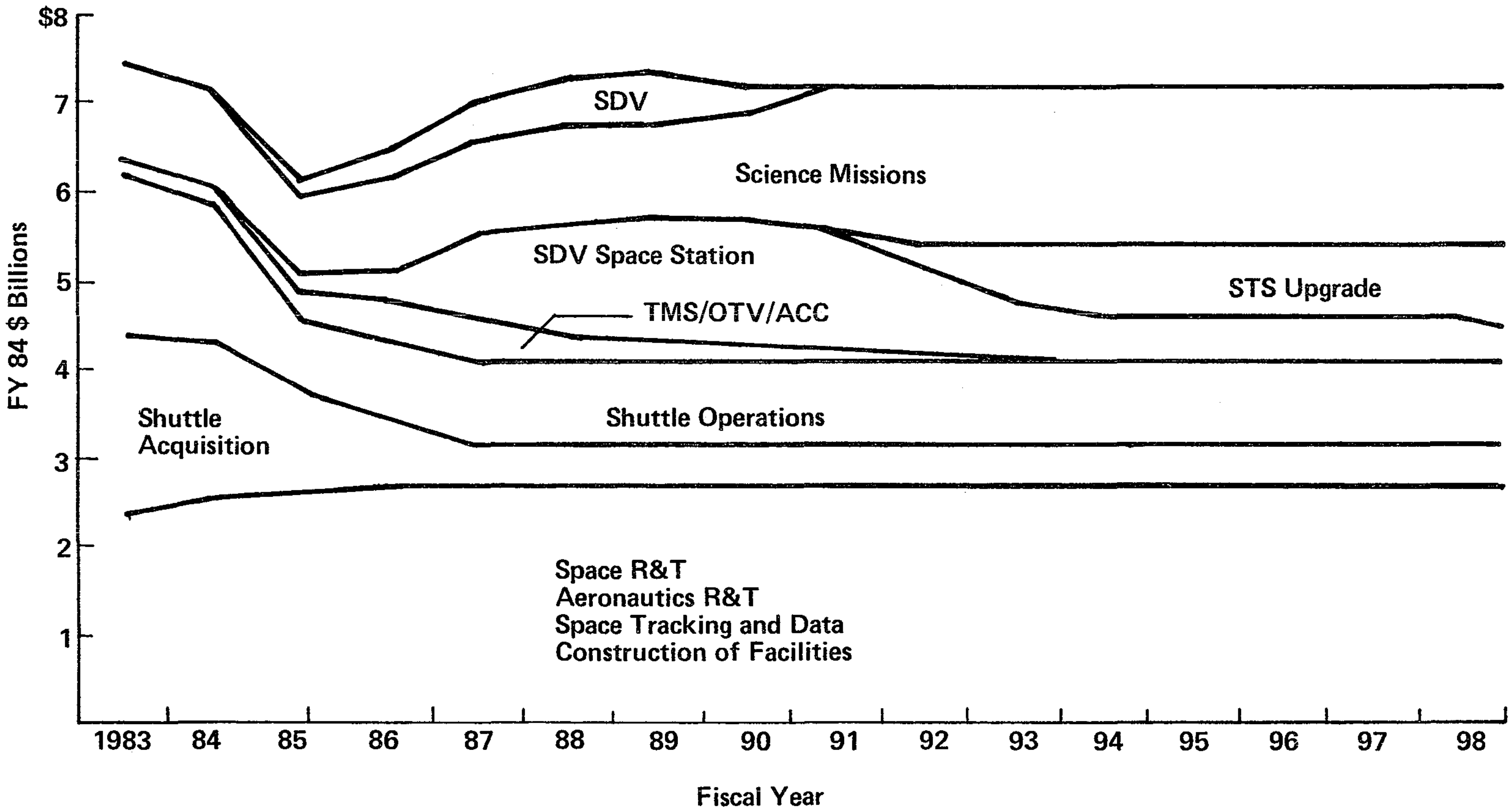
SDV Space Station Affordability Analysis – Baseline Science Budget





SDV Space Station Affordability Analysis – Constant Science Budget





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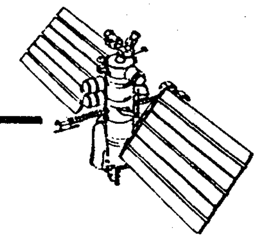
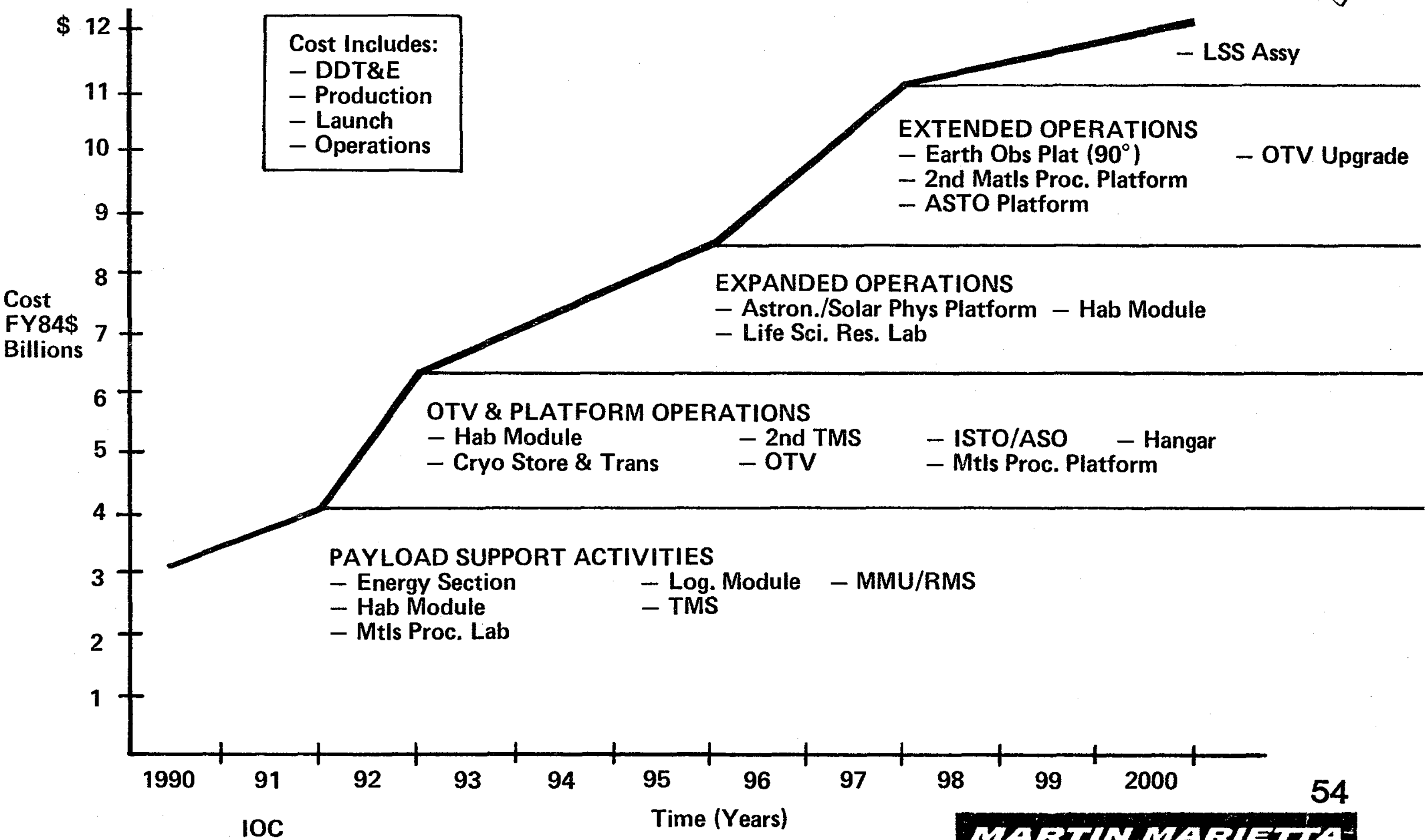
Space Station Cost By Evolution Increment – Modular Concept





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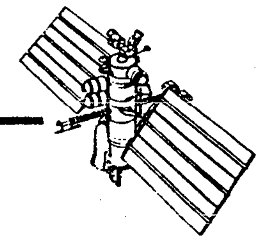
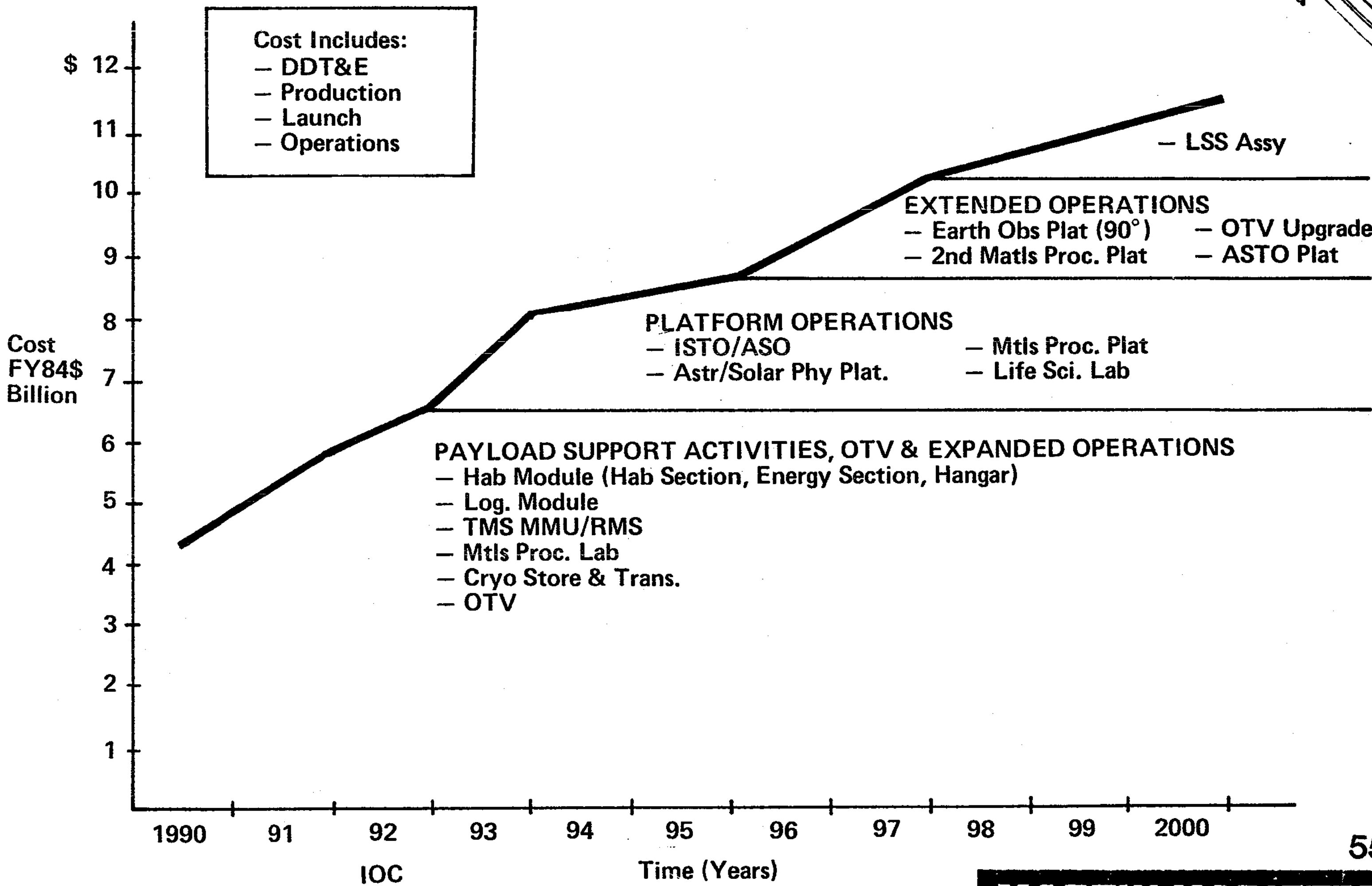
Space Station Cost By Evolution Increment – SDV Concept





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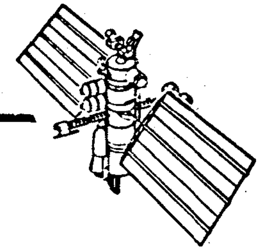
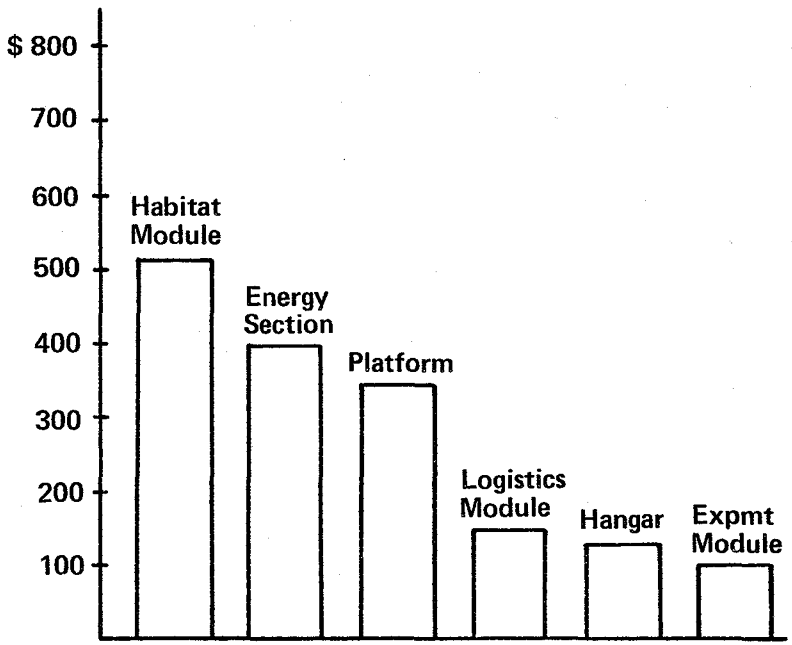
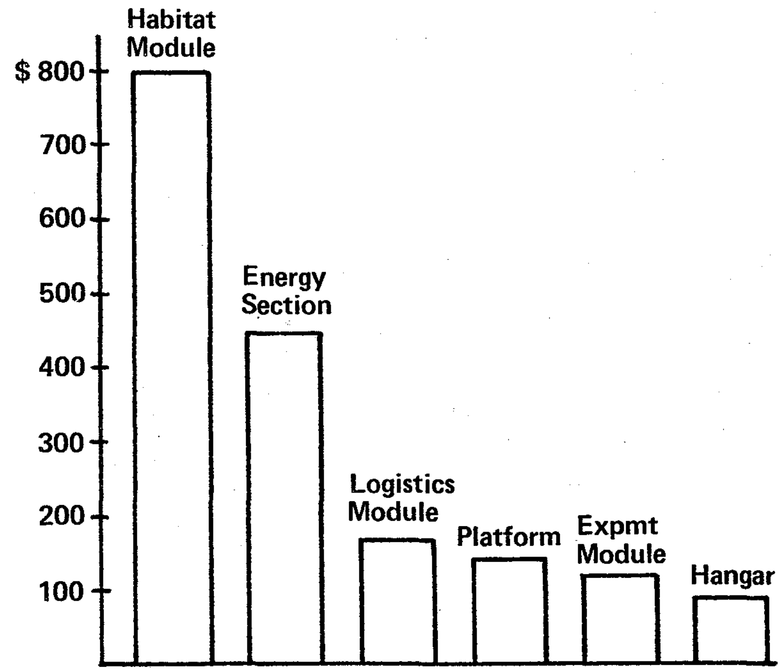
Space Station Cost Tall Poles



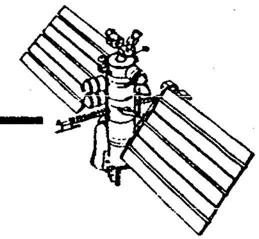


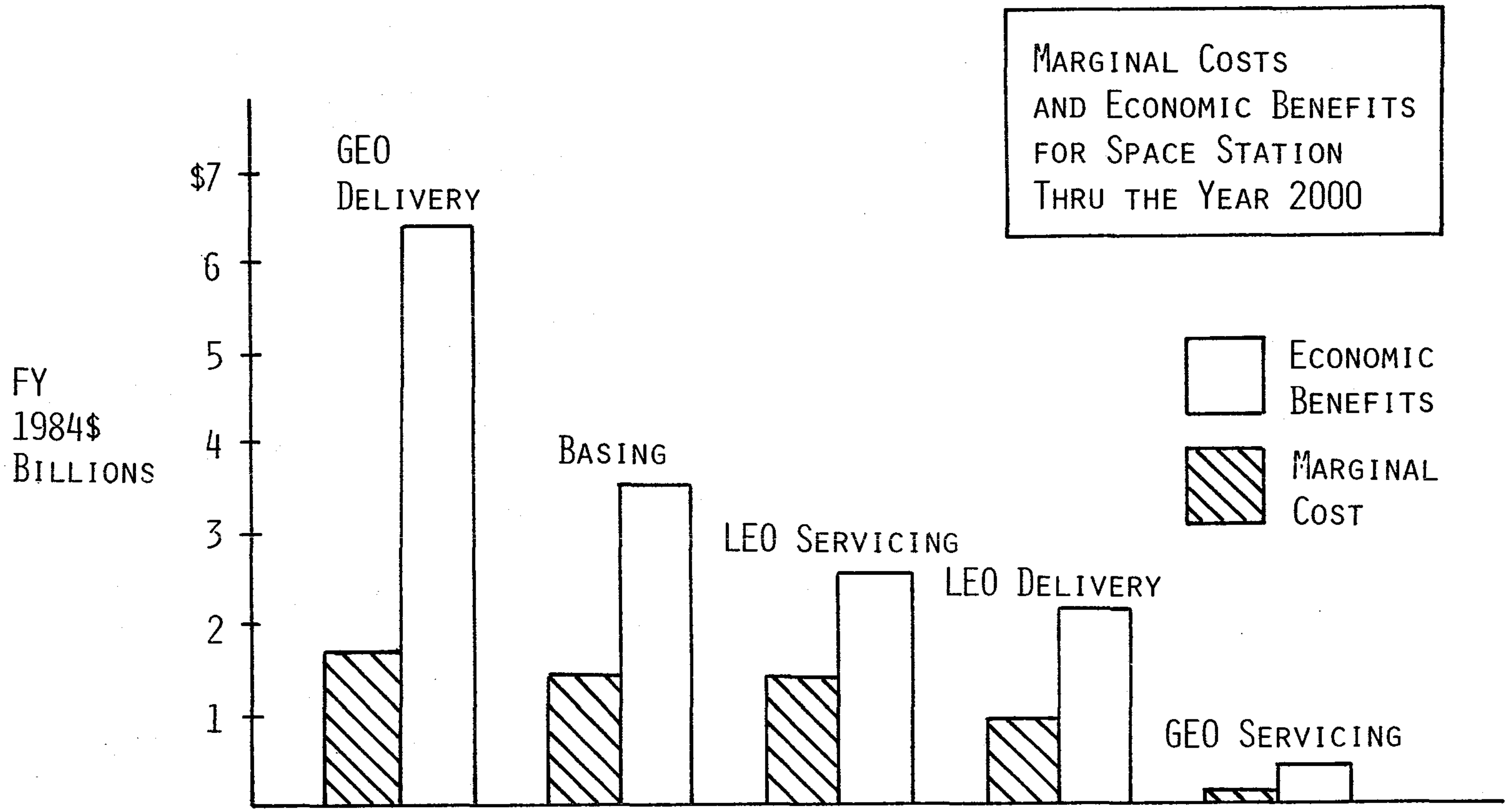
Development Cost Drivers
FY 1984 $ Millions



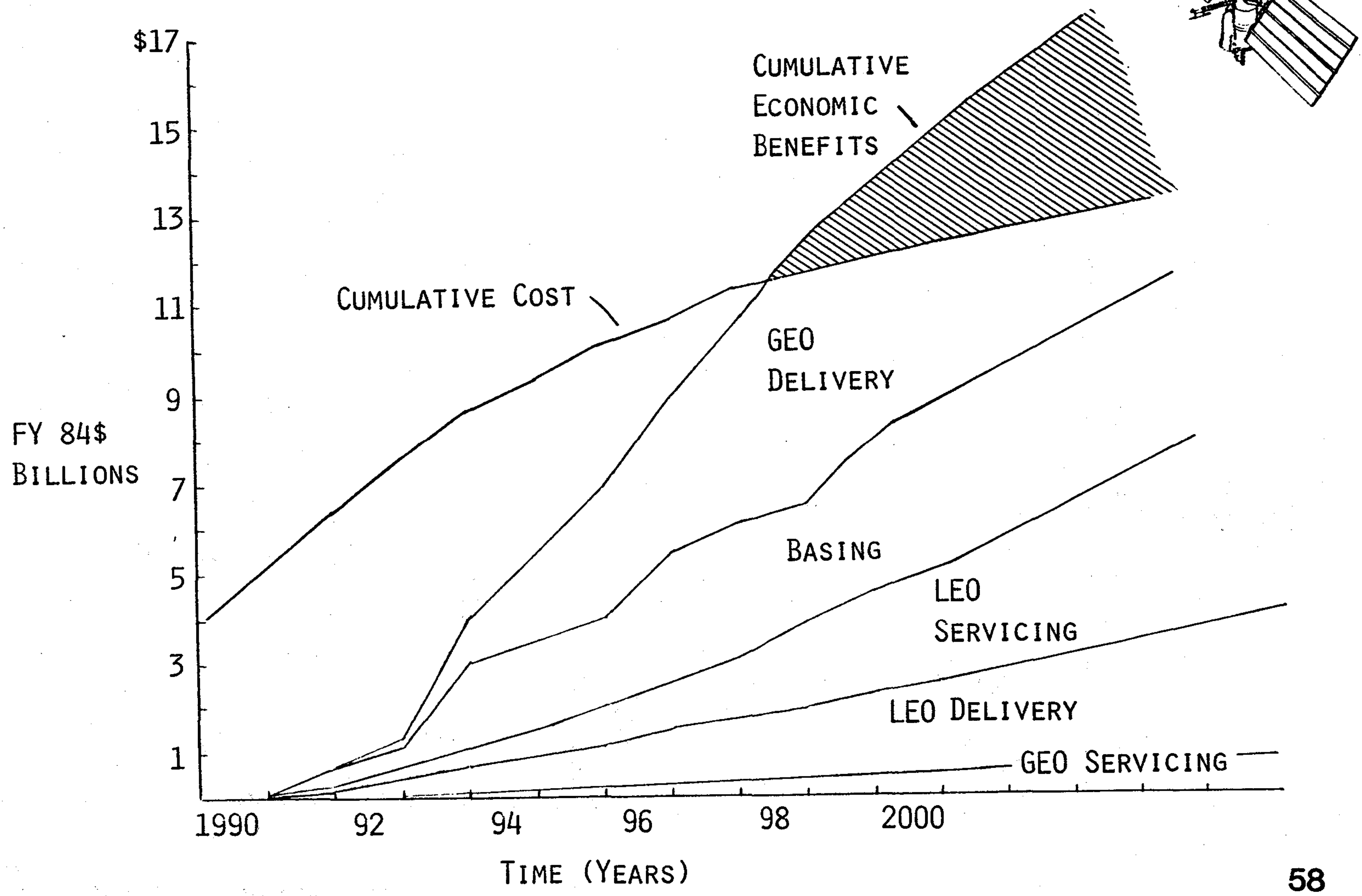
Unit Production Cost Drivers
FY 1984 $ Millions

Marginal Costs And Economic Benefits By Capability Increment





Cost/Benefit Breakeven Analysis – Modular Space Station 28.5°



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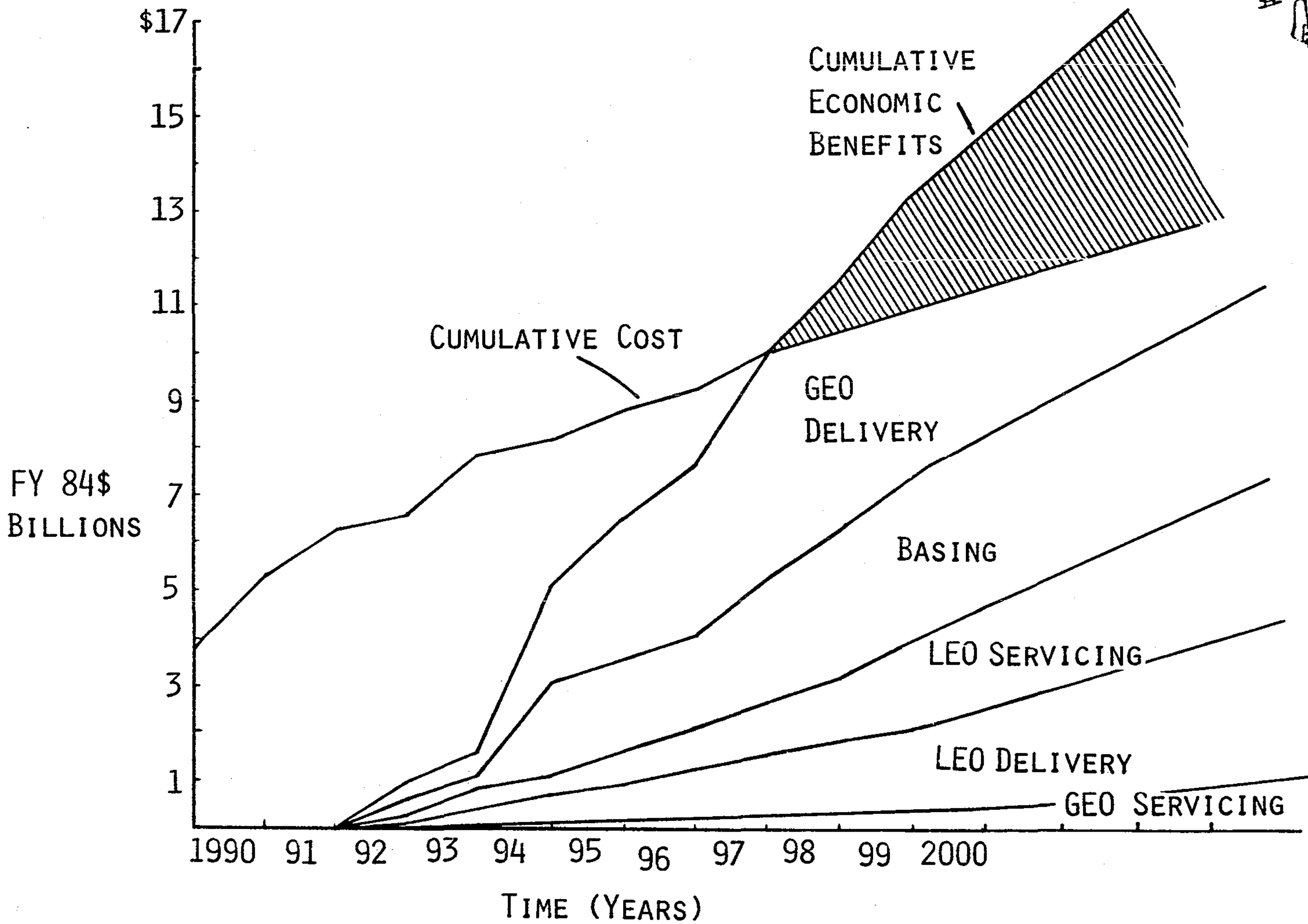
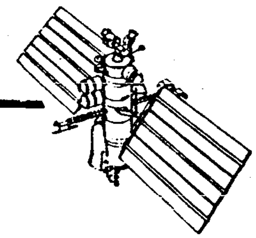
Cost/Benefit Breakeven Analysis - SDV Space Station 28.5°





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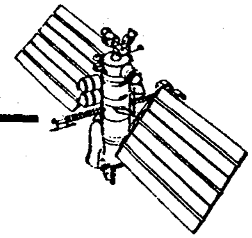
Space Station Benefits Summary



ECONOMIC

IN 10 YEARS OF OPERATION SPACE STATION PROVIDES:

- A SPACE TRANSPORTATION BASE THAT SAVES $8.6B
- A SUBSYSTEMS UTILITIES BASE THAT SAVES $3.6B
- A SPACE SERVICING CENTER THAT SAVES $3.0B

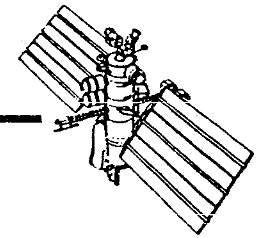
PERFORMANCE

SPACE STATION PROVIDES LONG TERM, UNIQUE CAPABILITY FOR:

- OBSERVATION
- MATERIALS PROCESSING RESEARCH
- LIFE SCIENCE RESEARCH
- REPAIR AND SERVICING
- LARGE VOLUME STRUCTURAL ASSEMBLY

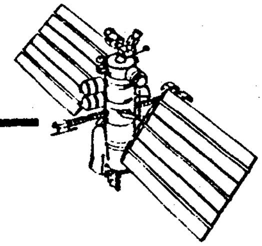
SOCIAL

- PROMOTES INTERNATIONAL COOPERATION IN SPACE SCIENCE, RESEARCH AND TECHNOLOGY
- MAINTAINS NATIONAL TECHNOLOGY ADVANCEMENT AND SPACE LEADERSHIP



Conclusions

Summary Conclusions



- SPACE STATION SYSTEM PROVIDES BOTH ECONOMIC AND PERFORMANCE BENEFITS
- SPACE STATION SYSTEM IS AFFORDABLE WITHIN PROJECTED NASA BUDGET CONSTRAINTS:
    - ACQUISITION OF SPACE STATION SYSTEM
    - EXPANDED SCIENCE AND APPLICATIONS PROGRAMS
- STS SUPPORT REQUIRED BY SPACE STATION IS WITHIN CURRENT FLEET CAPABILITIES
- EARLY MANNED PRESENCE IN LEO STATION IS JUSTIFIED:
    - TO SATISFY EXISTING USER REQUIREMENTS
    - MAXIMIZE PERFORMANCE AND ECONOMIC BENEFITS
    - PERFORM COMPLEX AND UNIQUE ASSEMBLY, C/O AND MAINTENANCE OPERATIONS

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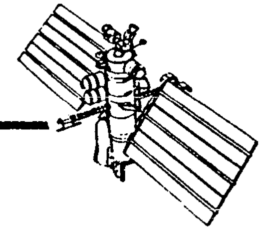
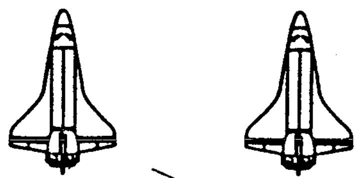
Space Station Payoffs

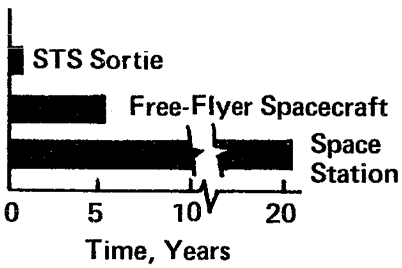


SPACE STATION A CAPABILITY MULTIPLIER

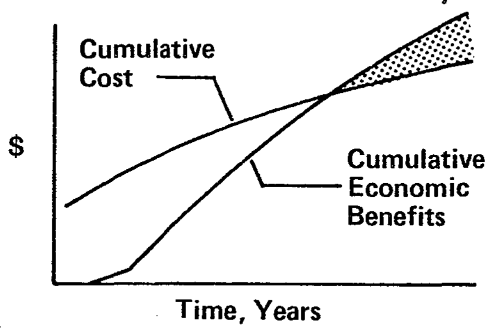
Equivalent to Two Additional Orbiters



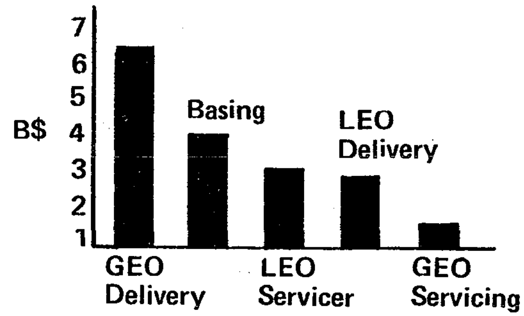
Extended Time Onorbit



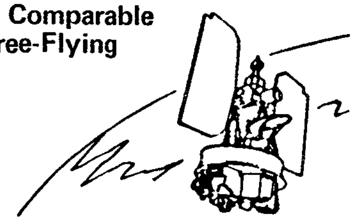
Benefits Exceed Cost Within Lifetime of System



Provides Significant Economic Benefit as Launch and Utilities Base



Provides Basing Comparable to Dozens of Free-Flying Spacecraft



Provides Long-Term, Unique Capability for

- Observation
- Materials Processing Research
- Life Science Research
- Repair & Servicing
- Large Volume Structural Assembly

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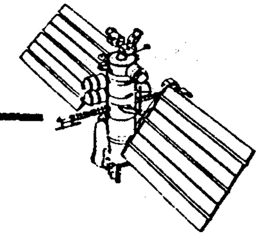
Summary Conclusions (Continued)



- Single Space Station at 28.5° supports 80% of user missions -- a second station at high inclination captures an additional 5% of the users at a 50% increase in cost

- Early Space Station Architecture should include:
  - Reusable OTV with aerobraking
  - TMS with telepresence servicer
  - OTV/TMS refueling and servicing capability
  - Attached research laboratories (Life Sci. & Mtls Proc.)

End of Document